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TECHNOLOGY TRANSFER PROGRAM (TTP)

FINAL REPORT

QUALITY ASSURANCE SYSTEM

QUALITY ASSURANCE

VOLUME 1 REPORT

Prepared by:

Levingston Shipbuilding Company
Orange, Texas

March 3, 1980

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PREFACE

This report is one of several emanating from the Shipbuilding Technology Transfer Program performed by Livingston Shipbuilding Company under a cost sharing contract with the U.S. Maritime Administration.

The material contained herein was developed from the study of the Quality Control and Accuracy Control systems presently in operation in the shipyards of Ishikawajima-Harima Heavy Industries (IHI) of Japan. Information for this study was derived from source documentation supplied by IHI, information obtained directly from IHI consulting personnel assigned on-site at Livingston, and from personal observations by two teams of Livingston personnel of actual operations at various IHI shipyards in Japan.

In order to place this study in context within the overall Technology . Transfer Program, a brief overview of the program and its organization is provided in the following paragraphs:

THE TECHNOLOGY TRANSFER PROGRAM (TTP)

The U.S. Shipbuilding Industry is well aware of the significant shipbuilding cost differences between the Japanese and ourselves. Many reasons have been offered to explain this differential and whether the reasons are valid or not, the fact remains that Japanese yards are consistently able to offer ships at a price of one-half to two-thirds below American prices.

Seeing this tremendous difference first hand in their own estimate of a bulk carrier slightly modified from the IHI Future 32 class design, Livingston management determined to not only find out why this was true but to also attempt to determine precise differences between IHI and Livingston engineering and design practices; production planning and control methods; facilities production processes, methods and techniques; quality assurance methods; and personnel organization, operations, and training. The obvious objective of such studies was to identify, examine and implement the Japanese systems, methods and processes which appeared to be applicable to Livingston and which promised a significant improvement in the Livingston design/production process.

With this objective in mind, and recognizing the potential application of the TTP results to the American shipbuilding industry, Livingston initiated a cost-sharing contract with MarAd to provide documentation and industry seminars to reveal program findings and production improvement results measured during production of the bulkers. Subsequently, Livingston subcontracted with IHI Marine Technology Inc. (an American corporation and a subsidiary of IHI, Japan) specifying the areas to be explored and the number and type of IHI consulting personnel required during the period of re-design and initial construction of the first bulker.

Basically, the program is organized into six major tasks:

1 - Cost Accounting

2 - Engineering and Design

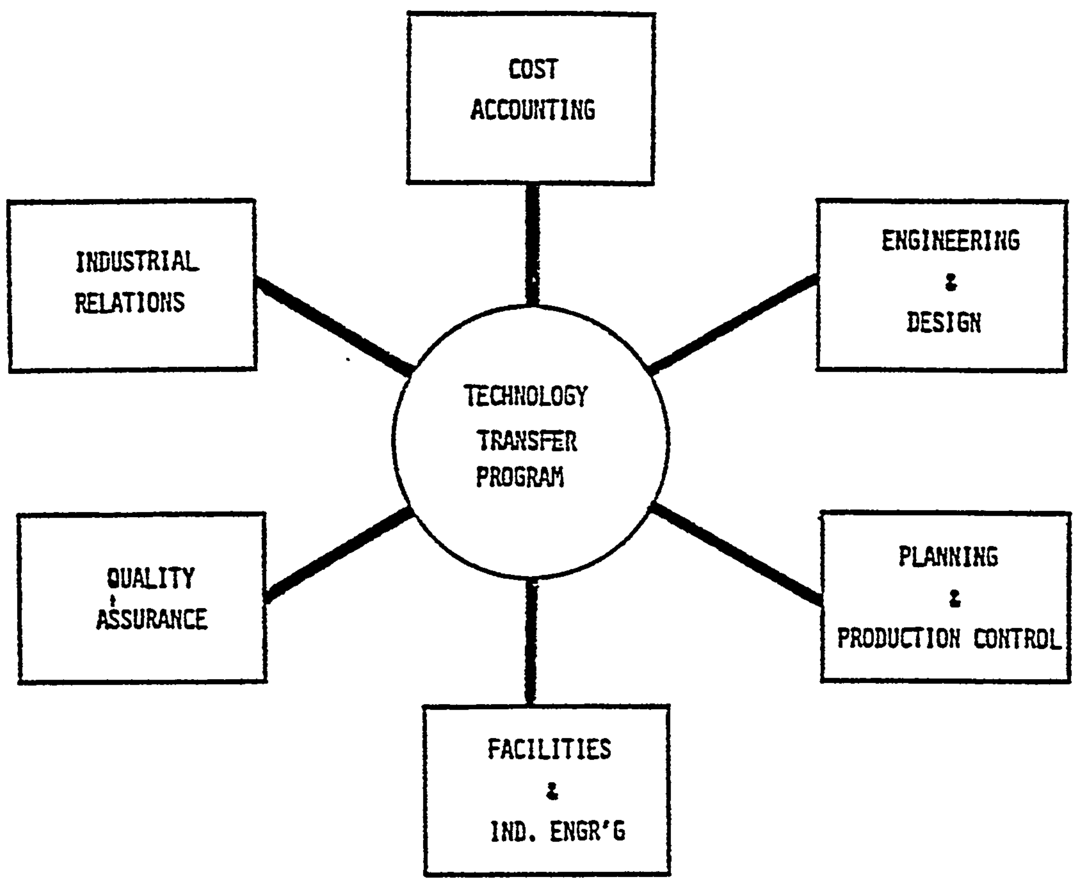
3 - Planning and Production Control

4- Facilities and Industrial Engineering

5 - Quality Assurance

6 - Industrial Relations

Beneath each of these major tasks is a series of sub-tasks which further delineate discrete areas of investigation and study. Each sub-task area has been planned and scheduled to: 1) study IHI systems, methods and techniques; 2) compare the Livingston and IHI practices; 3) identify improvements to the Livingston systems; 4) implement approved changes; 5) document program findings, changes to the Livingston systems, and the results of those changes; and 6) disseminate program findings and results to industry . via MarAd.



SECTION 1

INTRODUCTION

1.1 PURPOSE AND SCOPE

The purpose of this study was to analyze the Japanese (IHI) concept of Quality Assurance and its application in the actual working environment in IHI shipyards. As in the many other areas of study within the Technology Transfer Program (TTP] the objective of the study was to define possible beneficial and cost-saving elements or methodologies which could be instituted in Livingston and in other medium size shipyards in the United States.

In this examination of the IHI Quality Assurance concept and its application, two discrete but interrelated functions are discussed - Accuracy Control and Quality Control. These two functional elements comprise the organizational aspects of the IHI Quality Assurance concept, although as noted throughout the report the cognizance and execution of quality production pervades all functions and types of work.

1.2 ORGANIZATION OF REPORT

This report comprises two volumes: I - Findings & Conclusions and II - Appendices. This volume consists of four sections:

Section 1 - Introduction

Section 2 - The Japanese Approach to Quality Assurance

Section 3- The Accuracy Control Concept

Section 4- Quality Control

Sections 2, 3 and 4 comprise an account of the findings and an analysis of both the concepts employed and the actual functioning of these concepts in the IHI shipyards. A discussion of the implications of Accuracy Control as a Management Philosophy and the possibilities for achieving quality and cost benefits from the implementation of Accuracy Control in U.S. shipyards is included in Section 2.

The paragraphs in Section 2 covering the implementation of Accuracy Control within Levinston are an account of such implementation to the date of this report.

Several appendices (source data) are also included as Volume II of this report. These appendices are listed below:

Appendix	
A	Accuracy Control System
B	Planning of Vital Points of Accuracy
c	Base Line for Accuracy
D	Additional Material Planning
E	Accuracy Check Sheets
F	IHI SPAIS - The Shipbuilding Process and Inspection Standard
G	Standard & Tolerance For Keeping High Accuracy at IHI Aioi Shipyard
H	Schedule & Particulars of Inspection & Testing (Bulk Carrier)
I	Procedure of Official Sea Trial (Bulk Carrier)

SECTION 2

THE JAPANESE APPROACH TO QUALITY ASSURANCE

2.1 GENERAL

The function, organization and operation of quality Assurance within American shipyards is well known to all shipbuilders. The requirements of regulatory bodies and customers, both commercial and military, have necessitated a sophisticated and costly system to be evolved by shipyards to assure compliance to government and user regulations and specifications. This assurance requires manpower, special tools and test equipment, preparation of detailed test procedures, expenditures for test and inspection of purchased material and components, and extensive documentation and record keeping on a multitude of reports, inspections, corrections and proofs of operational adequacy. It is a safe assumption that these requirements add hundreds of thousands, if not millions of dollars to the cost of every ship produced in the United States.

The typical American approach to Quality Assurance has been to organize a separate entity within the company to deal with the peculiar aspects, of inspection, tests, and trials. Although there has been a determined effort to integrate aspects of Quality Assurance into the design process no significant benefits are derived by the majority of shipbuilders from such an activity. Further, Quality Assurance in the production process has, in most cases, been one of passive control, operating after-the-fact, and when the only recourse upon finding an error or other deficiency was to require re-work of the affected part. American shipyards do indeed build quality ships but in many shipyards the quality assurance activity is regarded as an expensive but contracturally-necessary nuisance that compromises production schedules and ultimately profits.

The requirements of Quality Assurance faced by the Japanese are not dissimilar to those confronting American shipbuilding. However, the approach to Quality Assurance is radically different. Quality is an overriding consideration in all products built by the Japanese and their concern for this single aspect of their product is manifest throughout the shipbuilding process from the governing policy of the company's President to the personal pride in craftsmanship demonstrated by the workers on every level. Quality Assurance has become an integral part of the skill of every worker, supervisor and manager in IHI and is an accepted and even desirable characteristic of every job.

The implications of such an attitude in terms of product quality, cost savings and productivity are significant and make the Japanese system worthy of study and consideration for possible implementation 'in American - yards.

2.2 THE IHI CONCEPT OF QUALITY ASSURANCE

IHI Quality Assurance cannot be identified as a separate function or organization. Rather, it is a management, design and production philosophy found in continuous application at all levels of the organization. This philosophy is manifest in two discrete organizational elements: 1) several Accuracy Control groups functioning within the Design Department and in the three workshops (i.e. hull, fitting and panel), and 2) the Quality Control Department. Each of these groups operate in conjunction with the Production Planning and Engineering groups also in the three workshops.

The IHI Quality Assurance function can best be described as an interactive system comprising the elements of regulatory body and customer specification requirements, IHI design/production standards, and Accuracy Control requirements. These data form the basis for all design and production activities. (see Figure 2-1). Quality Assurance is, therefore, a concept or philosophy underlying the production systems of IHI shipyards rather than a specifically defined organization whose charter is to "police" the end result of various production processes.

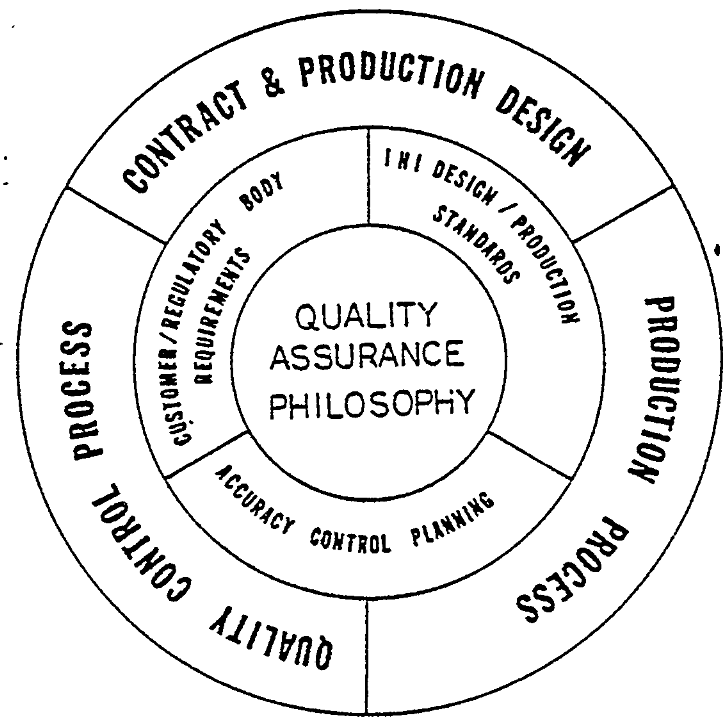


Figure 2-1

Quality Assurance Concept

Within IHI the Accuracy Control groups and the Quality Control Department function to prescribe the vital dimensions, measurements and tolerances which must be observed during the production process and to assure that the work has been accomplished in accordance with specification or standards requirements. The primary group (Accuracy Control) is really four groups of engineers working in design, the panel workshop, the hull workshop and the fitting workshop. Each group supports a specific workshop developing the accuracy planning and activities throughout the hull construction and outfitting process. These groups work closely with each other and with the Planning and Engineering staffs of each workshop and with Quality Control. The second group, Quality Control, performs the traditional inspections required by customer specifications and regulatory bodies. It is also active in the sampling of weldments by various NDT methods and in routine inspections during fabrication, assembly, erection and outfitting.

The majority of inspection is performed by the workers at all stages of production. For example, warehousemen perform all material and component receiving inspection except for special components which are not routinely purchased. welders perform a self-check of all of their work and when satisfied identify their work by affixing their signature. Another worker in each group (usually six to eight people) is assigned permanent responsibility for checking the quality of the work accomplished by all members of his group. This “checker” has no other duties. Each group’s work is also inspected by the responsible assistant foreman prior to acceptance and movement of the piece or assembly under construction. Sample inspections are performed on approximately five percent of the total work by a Quality Control inspector.

This high degree of quality consciousness and checking in the production process naturally results in a superior product. However, what is not obvious is that this concern for quality also greatly increases productivity and worker effectiveness. The Japanese workman, with his emphasis on quality, does not pass on mistakes or faulty workmanship to the next

production station. All work is done correctly to established standards and is clean and free from defects or residue which would have to be corrected or cleaned up by following work stations. Therefore, each workman is unencumbered in performing his specific task and can proceed expeditiously without any delay caused by prior work. This allows precise measurement of time requirements for each job and work activity is therefore rigorously scheduled literally on an hour-by-hour basis.

SECTION 3

THE ACCURACY CONTROL CONCEPT

3.1 GENERAL

Though Quality Control is a recognized and highly perfected discipline in IHI, it is actually the function of "Accuracy Control" that is the basis for all Quality Control action and operation. In IHI, Accuracy Control is a system inherent in the design and production process including Engineering, Mold Lofting, Marking, Gas Cutting, Bending, Welding, Sub-assembly, Assembly, Erection and all outfitting activities. It is through the Accuracy Control system that the shipyard attempts and eventually realizes high quality ships produced by a highly perfected and efficient production process and at extremely low cost.

Accuracy Control's principal objectives are to perfect each production method, technique and process to such a degree that each worker activity has definitive standards to be achieved, a prescribed method of measurement for finished material, and a continuous flow of information between activities resulting in the constant improvement of product quality and production efficiency.

The basic operating premise of Accuracy Control is to keep high accuracy in the shape of the major hull units at the erection stage. The objective of this accuracy is to minimize the number of labor hours and the difficulty of the work during erection. This is accomplished through a sophisticated system of standards, "Check Sheets", inspections and measurements during each phase of ship construction such as: lofting, component/subassembly fabrication, and unit assembly. The motivation for such a philosophy is obvious in that all shipbuilders know that the"work performed during erection can require an inordinate amount of time if the erection units are not properly sized, cut, held to tolerance, etc. Work during this stage of construction is typically more difficult, more dangerous, more time-consuming and more costly than any of the work which preceded it. Therefore, IHI emphasizes superior quality work at each stage of production to reduce this one aspect of ship construction. The methods by which this is accomplished are detailed in the following paragraphs.

Essentially, the Accuracy Control activity comprises three elements: planning, field activity, and information feed-back. The planning activity consists of:

Participation in determining the breakdown of the ship into hull blocks (or units/modules)

Participation in determining shell straking

Participation in determining the optimum erection sequence

Participation in determining assembly sequence and methods

Participation in determining fabrication sequence and methods

Development of the Vital Points and Dimensions to be measured to maintain part or unit accuracy

Development of a scheme of Added Material to optimize assembly and erection

Development of Base Lines for lofting and measurements

Development of tolerance standards for components and assemblies

Based on this information, which is also used by Engineers in the development of working drawings, Accuracy Control Field Activity personnel develop Check Sheets for each ship unit, identify precise dimensions for each unit, and develop template designs for measuring fabricated pieces and components.

Subsequently, actual field measurement of fabricated pieces, components, sub-assemblies and assemblies is accomplished and data is recorded for analysis and feed-back to engineering, lofting, planning or the production functions involved in the fabrication process.

Figure 3-1 illustrates the general flow of production units and the activities and objectives of Accuracy Control at each production stage. As shown in the figure, Accuracy Control prescribes all necessary dimensions and tolerances to achieve the required precision at each stage of fabrication (i.e. marking, cutting, bending and sub-assembly). The fabricated pieces and sub-assemblies then undergo similar inspections as they are assembled into flat or curved assemblies. At each stage dimensions and tolerances are measured prior to moving a unit from each work station and any deficiencies corrected. This results in an extremely smooth flow of material throughout the production process.

The activities of the various Accuracy Control groups (i.e. Panel Workshop, Hull Workshop and Fitting Workshop groups) are started well before the beginning of the development of working drawings. Accuracy Control planning is initiated (on the basis of the preliminary basic design) several months prior to the start of fabrication. During this planning the vast number of established standards continuously in use by the shipyard for every type of ship, are reviewed and revised as necessary to accommodate unique features specified by the customer. The greatest effort in the planning stage is the development of the vital points and dimensions of components, sub-assemblies and assemblies which must be

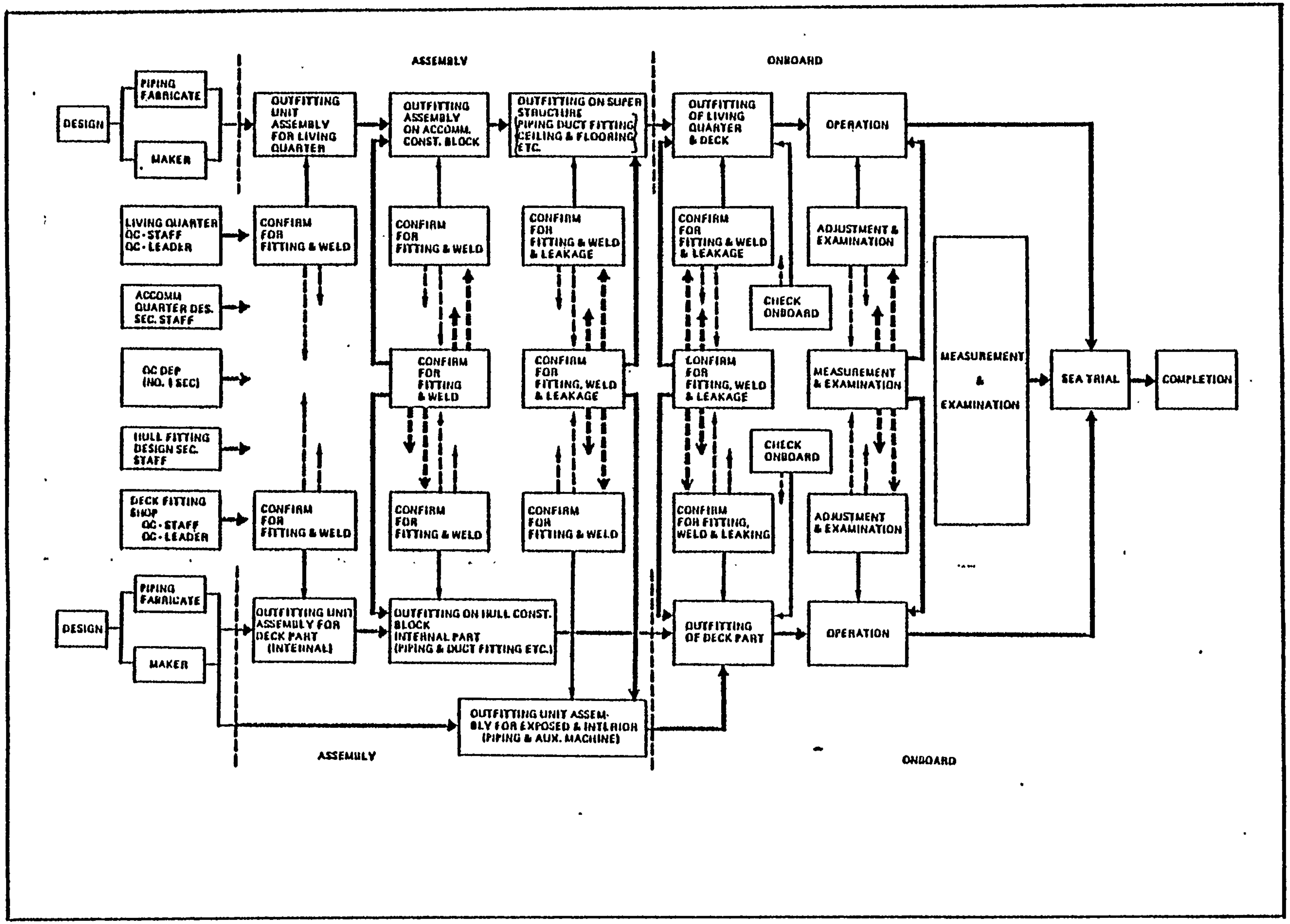
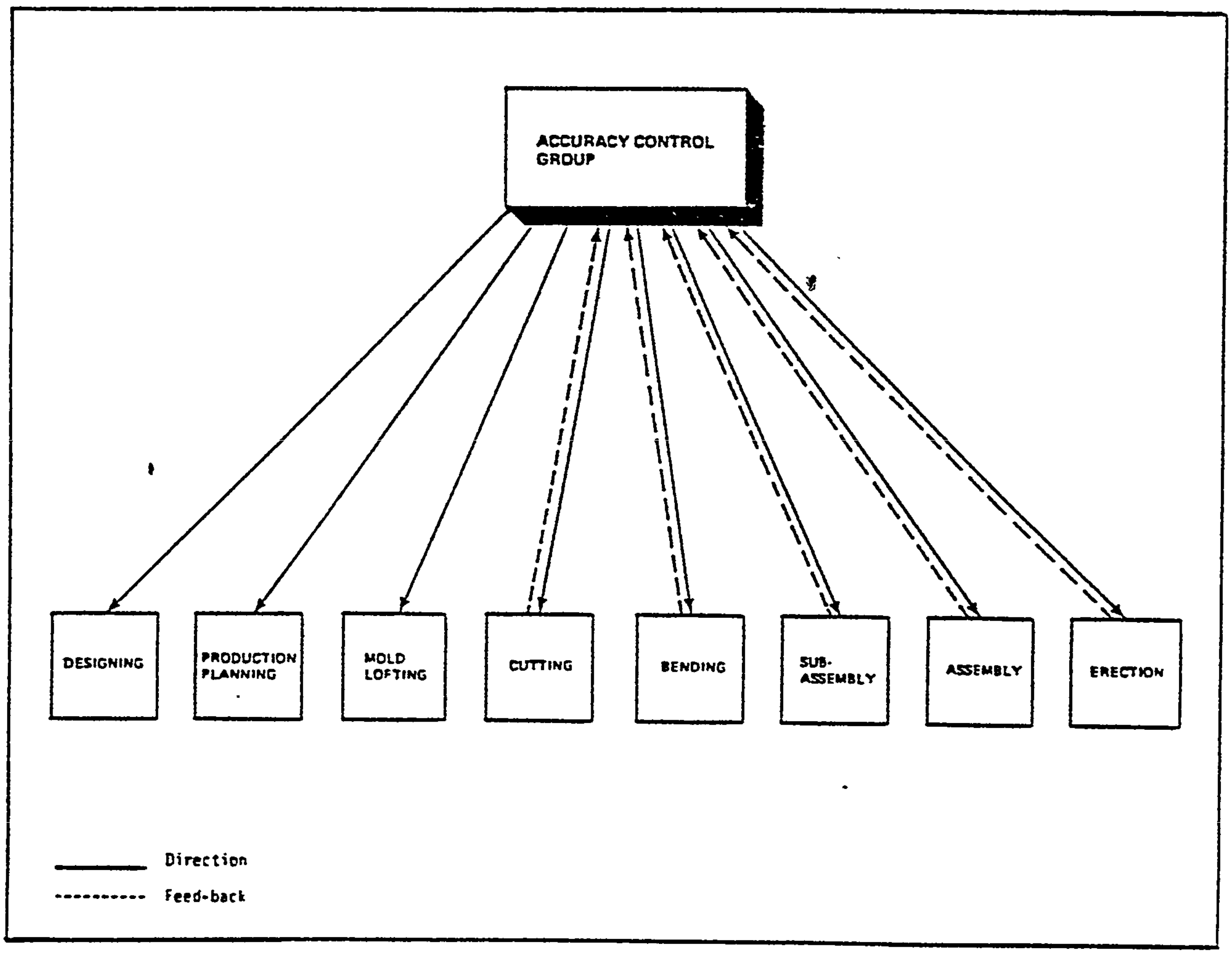


FIGURE 4-6 QUALITY CONTROL FLOW CHART (HULL FITTING) (IHI)

maintained during production, the development of the scheme of added material, the identification of base lines for lofting and measurements, and the specific tolerances that must be held if high accuracy.is to be obtained.

In this planning and throughout its application the four Accuracy Control groups interface with all shipyard activities. Much of this interface consists of a "feed-back" or coordination of information as it evolves during actual design and production. Figure 3-2 shows this interface activity and the various "feed-back" loops of information flow.



3.2 ACCURACY CONTROL IN THE PLANNING & DESIGN PROCESS
[See Appendices A, B, C, D)

Accuracy Control planning begins immediately upon completion of the basic design. This basic design consists of drawings of: LINES (not faired), MIDSHIP SECTION, CONSTRUCTION PROFILE, GENERAL ARRANGEMENT and MACHINERY ARRANGEMENT. The Accuracy Control groups participates in developing the Block (module) division of the ship and the erection sequence. Various studies are then initiated on major ship sections, such as cargo holds, since these sections are considered the most essential for construction of the hull. These sections also represent the starting point for development of accuracy control requirements for curved (bottom) assemblies. Fabrication methods for cargo hold units and curved units are studied, the best methods determined, and the plan for shipwrighting is developed. Welding methods are determined for each assembly and vital points and dimensions are determined for maintaining high accuracy at each production stage.

In parallel with this basic planning, preliminary drawings for Shell Expansion, Upper Deck Plan, Inner Bottom Plan, inboard profiles and major ship sections are developed. Detailed fabrication methods and Accuracy Control planning are further refined and developed for all assembly units on the basis of these drawings. Upon completion of this work the shipyard Design group begins development of detailed working drawings.

During this planning stage the Accuracy Control groups prepare the basic.data which will guide production and the quality assurance activities throughout the shipbuilding process. These data consist of:

The Scheme for Added Material

Shipwrighting at Erection

Plan for Finishing Up

Check Points, Unit Dimensions, and Checking Methods at Sub-assembly, Assembly and Erection

Vital Points During Fabrication (i.e. marking, gas cutting and sub-assembly)

Baselines To Be Obtained From The Output of Mold Lofting

Fabricating Sequence and Methods for Each Unit

Welding Methods (with consideration for shrinkage) and Dimensions of Added Material

These documents serve as guidance for design engineers in the preparation of working drawings and for all subsequent planning for fabrication, assembly and erection.

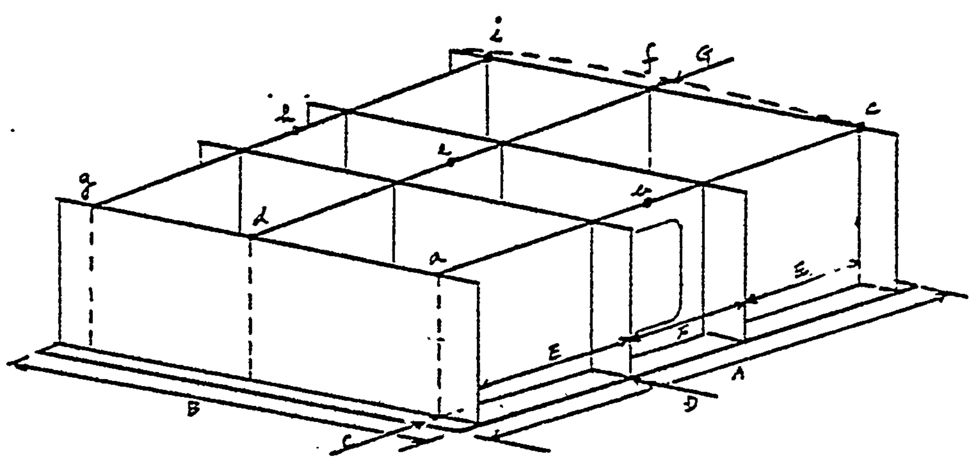
3.3 ACCURACY CONTROL IN THE PRODUCTION PROCESS (See Appendix E)

During initial production Accuracy Control planning is put into use. Accuracy Control activity in production begins in the area of mold lofting where vital points and dimensions are specified for templates and plate layouts. Methods to be used for burning and measurements of cut plates are also specified. The fabrication sequence is implemented through detailed schedules prepared for.every level of work and measurement requirements are instituted by means of the Accuracy Control Check Sheets (see Figure 3-3 thru 3-6). During the Production Planning phase, the Accuracy Control groups prepare a Check Sheet for each unit of the ship. This Check Sheet defines the points to be measured, the checking method, personnel responsible for the checking, and the frequency of measurement required. Examples of these check sheets are provided in the above referenced figures and in Appendix H of this report.

Using these Check Sheets measurement of fabricated steel and units is performed using instruments such as scales, wire, transits, plummets and

ACCURACY CHECK SHEET

Ship No.	Unit No.	Shop	Condition
			Before combined with bottom plate

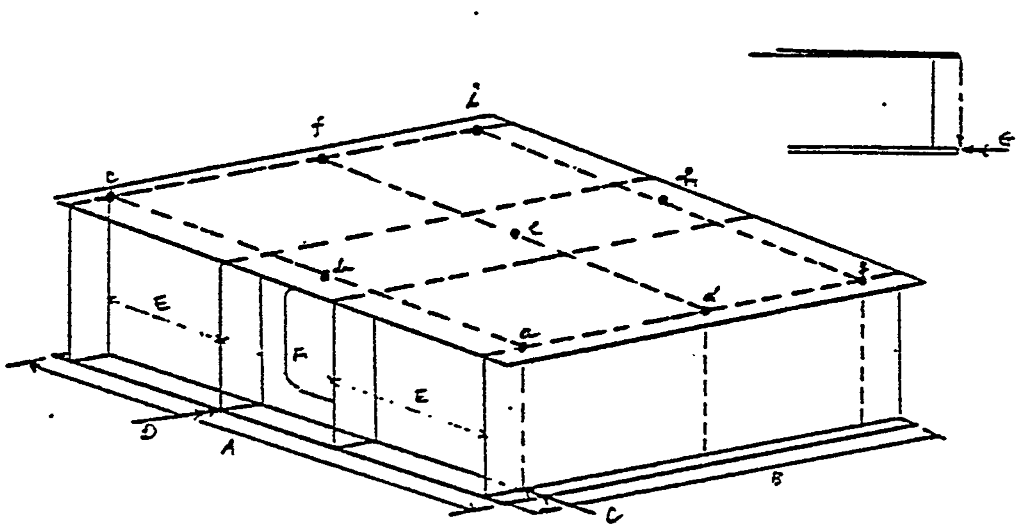


Mark	Item	Dim's in Drawings	Allow. Tol.	Actual Dimension	Chg.	Notice
C			P S		Worker AC	Both side (P.S)
D	Edge Alignment		F A		"	Every Girder Both Side (F.A.)
E	Girder Spacing		P S		"	Every Frame
F	"			FORE AFT	"	Both side (F.A.)
G	Straightness				"	Each girder show maximum.
H	Level			a b c d e f g h i j	"	9 points a - i

Noticc: After fitting, welding

FIGURE 3-3 EXAMPLE: ACCURACY CHECK SHEET

ACCURACY CHECK SHEET			
Ship No.	Unit No.	Shop	Condition
			Final Unit Assembly



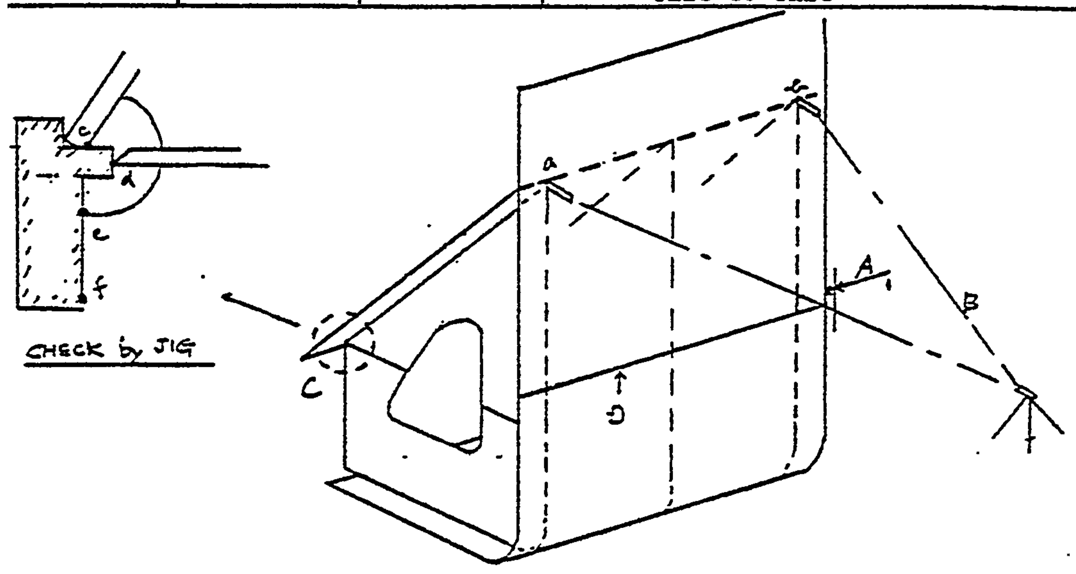
Mark	Item	Dim's in Drawings	Allow. Tol.	Actual Dimension	Chg.	Notice
C				P S	Worker AC	Both side (PSI) Each Frame
D	Edge Alignment			F A	"	Every Girder Both side (F.A)
E	Girder Spacing			P S	"	Every Frame
F	"				"	Both Side (F.A.)
G	Relativity				"	2 points each edge
H	Level			a b c d e f g h i j		9 Points (a-i)

Notice After fitting,welding

FIGURE 3-4 EXAMPLE: .ACCURACY CHECK SHEET

ACCURACY CHECK SHEET

Ship No.	Unit No.	Shop	Condition
			Unit to Unit



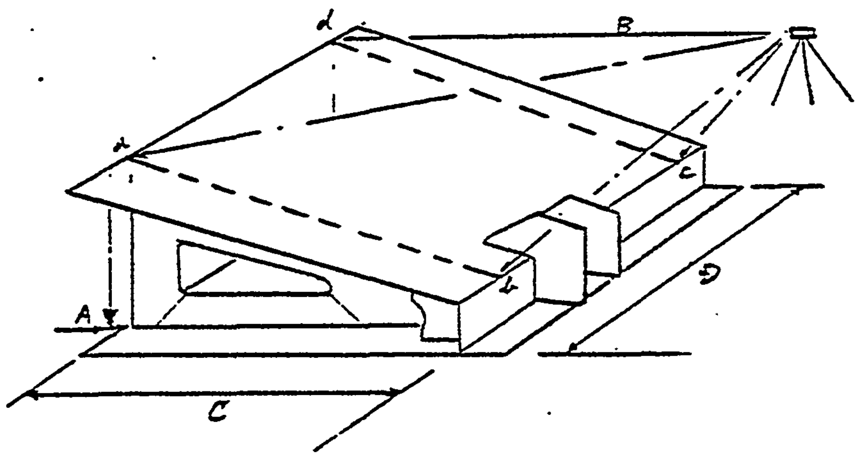
Mark	Item	Dim's in Drawings	Allow. Tol.	Actual Dimension	Chg.	Notice
A	Butt Alignment			FORE / AFT	Worker	Both side (A.F.)
B	Inclination			FORE / AFT	Worker AC	(a,b)
C	Alignment			c / d / e / f	"	Check by special jig.

Notice
1. After fitting and welding
2. Top seam at bilge should be checked and finished up before setting side shell unit.

FIGURE 3-5. EXAMPLE: ACCURACY CHECK SHEET

ACCURACY CHECK SHEET

Ship No.	Unit No.	Shop	Condition
			Before final unit assembly under the base of the Upper Deck.



Mark	Item	Dim's in Drawings	Allow. Tol.	Actual Dimension	Chg.	Notice
A	Shift between U.Dk. & Top Side				Worker AC	Every Frame
B	Level				"	4 points (a-d)
C	Width				"	
D	Length				"	

Notice: After fitting, welding

FIGURE 3-6 EXAMPLE: ACCURACY CHECK SHEET special jigs used for unique parts not amenable to measurement by ordinary techniques.

It is during this stage of production that the process described in Section 4- Quality Control, comes into play. The Accuracy Control Check Sheets are used by workers, group checkers, assistant foremen, and Quality Control Inspectors as the guiding information in the fabrication and assembly of all parts of the ship. Use of the Accuracy Control Check Sheets and the IHI Standards manuals provide complete information as to the dimensions, methods and other requirements expected from the production process. Nothing is left to quesswork on the part of workers or their, supervisors.

3.4 DATA ANALYSIS & FEED-BACK

One of the most important aspects of Accuracy Control is the analysis and feed-back of data collected throughout the production process. As previously mentioned, it is this continuing "purification" of planning data that eventually allows such high product quality and contributes to the extraordinary productivity of the IHI shipyards.

Each piece and part is measured at successive stages of its progression through the production process. The measurement of these pieces determines whether or not the piece is within the specified tolerance. Still, the Japanese are acutely aware of the effects of cumulative errors or marginally acceptable materials as they progress through the building process. They recognize the importance of identifying and correcting persistent marginal errors and even the tendency toward persistent errors in specific production areas or processes. As a result, they have adopted a statistical analysis method to examine and reduce errors that recur persistently throughout the building of a specific ship type. This statistical analysis method is based on the data accumulated through the use of the Quality Control Check Sheet discussed in paragraph 4.3.. The data thus gathered is analyzed to determine the possible causes and the implications of the error on “downstream” work.

The Accuracy Control Engineer analyzing the error may: Continue a more detailed investigation; review the fabrication method; investigate the measurement instruments and methods; investigate the foundation (such as the platform at assembly or cribbing at erection); investigate the adequacy of the added material. Based on the statistical findings the Engineer may deduce that the fabrication method itself yields a large variance and may result in out-of-tolerance errors. In this case he will take steps to perfect the fabrication method to obtain uniform and acceptable results on each piece so fabricated. This may involve a change in fabrication sequence, methods, personnel training or adoption of an entirely new fabrication process.

Accuracy Control .Engineers follows simplistic but highly effective regimen of “Plan - Do - See - Action” wherein they accomplish the planning, observe the production operation(s) accomplished under such planning, and, based on the data accumulated from such observations and from Accuracy Control prescribed measurements, take the necessary action to remedy or perfect the production method to achieve the desired results.

From analysis of the measurement data, appropriate action is taken by the Accuracy Control Engineer through “feed-back” of information to the applicable department or group. This feed-back is a vital loop in the overall Accuracy Control scheme and not only prevents errors from recurring, but provides the action necessary to the continuing improvement of product and production system. Examples of this feed-back are: a change to the dimension of added material requires a modification to the working drawing, therefore Engineering is so notified; an addition of Baselines in the output of the mold loft requires feed-back to the loft; a change in the fabrication method, or the platorm at assembly or welding procedure requires feed-back to Production and to the Planning and Design Staff responsible for a given workshop. Figure 3-7 indicates the feed-back flow of information accomplished by Accuracy Control groups.

3.5 THE USE OF ACCURACY CONTROL AS A MANAGEMENT PHILOSOPHY

Approximately 15 years ago the President of IHI instituted a new management philosophy that subsequently changed the entire operational concept of the corporation and which is today responsible for the exceptionally high productivity of IHI shipyards and quality of the IHI products. At that time the emphasis, which had been based on the American inspired profit motive, was changed to one of quality products and to an almost ideal concept of "welfare capitalism". Since this report deals with the quality aspect of ship products, only that aspect is discussed here. The latter concept (i.e. "welfare capitalism") is discussed in the report on Industrial Relations.

This change in management philosophy was initiated by reorganization of the IHI companies and through basic policy statements such as the one by IHI's President, Hisashi Shinto, quoted below:

> "Products that profit the client are what we aim to provide. The source of energy for pursuing this aim is technological capability. Dazzling innovations are not our object; we seek rather to build up - stone by stone - the basic technology to serve us in producing equipment that will benefit the customer in the long run. This we consider our mission; and technology understood in this light, is what sustains the vitality of our company."

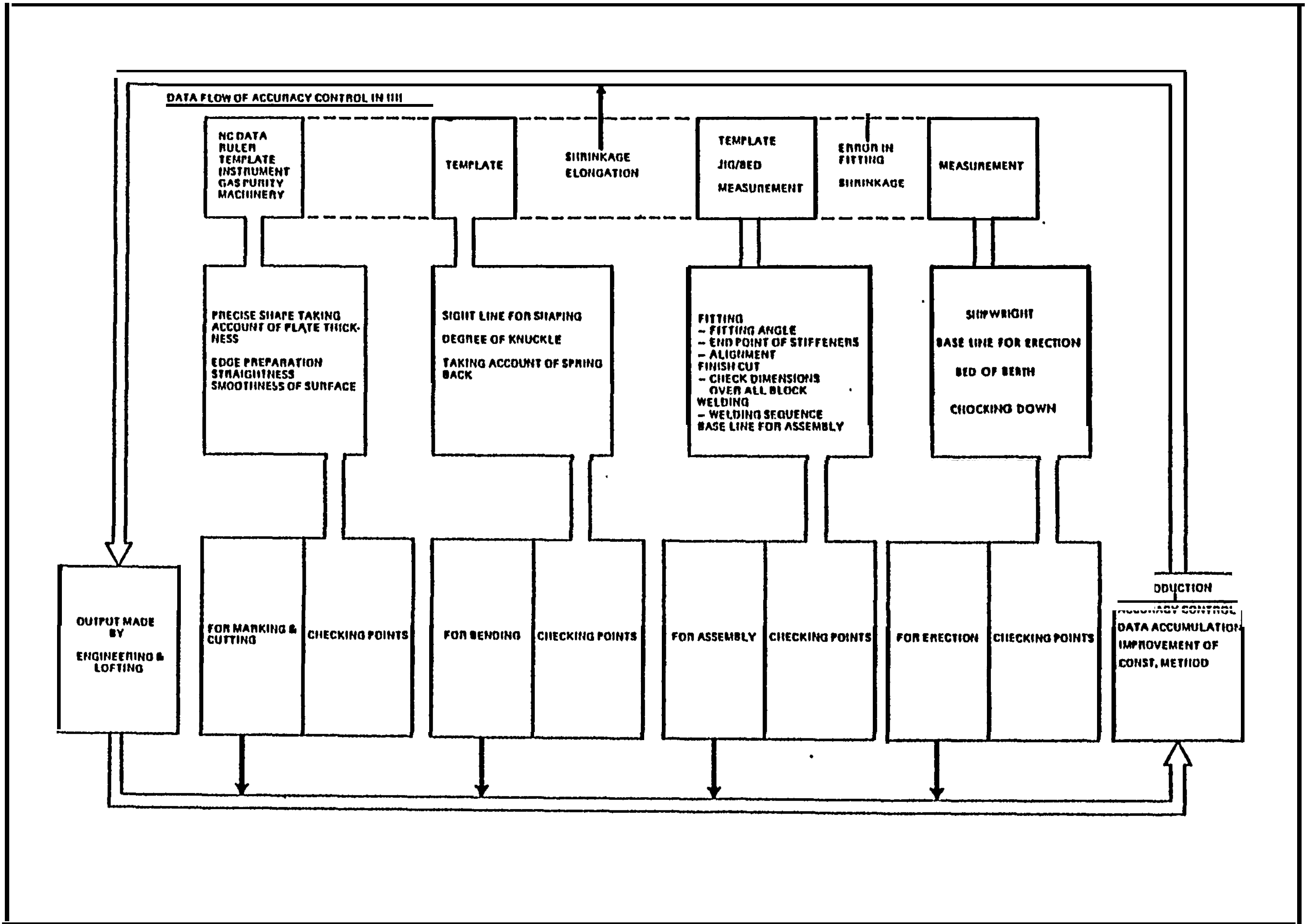


FIGURE 3-7 DATA FLOW OF ACCURACY IN IHI

This emphasis on "products that profit the client" and on "technological capability" has resulted in a dynamic and self-perfecting system which permeates every activity of the IHI shipyards. Coupled with an overriding ,concern for the welfare of the individual worker this emphasis on product quality provides a realistic and meaningful goal for IHI management and workers and, as corroborated by IHI fiscal reports, has ultimately resulted in profitable returns for the corporation.

The development of the Accuracy Control concept was the offspring of this management philosophy. The application of the concept to the actual production process required many years of trial and error, but once the basic process was established, its gradual integration into the production process and its step-by-step improvement was begun. Since its inception, Accuracy Control and its counterpart, Quality Control, have developed into the "standard" method for governing ship construction.

The concept of Accuracy Control, rather than the implementing groups, is what is important in IHI shipbuilding, and because of this it pervades all work and all levels of personnel with a concern for good workmanship and exactness. When examined from a purely production standpoint, its many benefits are immediately apparent. If all work required at each work station is expertly performed to exacting standards all successive work becomes easier and demands only the time required for the work planned for each station. It is axiomatic that errors passed from one work station to the next tend to compound themselves and quickly disturb planned manhours and schedules. Therefore, if the production system can be perfected (through the application of Accuracy Control or any other means) to provide only precise and error-free material as it flows through the building process, an increase in productivity can be effected. Naturally, an increase in productivity ultimately results either in increased profits or in the ability to decrease bid prices to customers thereby improving marketing possibilities. The Accuracy Control concept is equally important as a tool for shipyard management, particularly middle or first-line managers. Both detail design and production planning are influenced by the Accuracy Control activity during the planning phase prior to the start of working drawing development. The fabrication sequence and the techniques and methods to be used to achieve the highest accuracy and throughput are also directly influenced by Accuracy Control planning. Accuracy Control standards and Check Sheets prescribe the necessary workmanship requirements for each piece part and each successive unit. Prescribed measurements and measurement methods and instruments are the result of Accuracy Control study and planning. The erection sequence and the plan for shipwrighting, both resulting from Accuracy Control activity, detail the flow and work requirements for final ship construction and finishing.

Over the years these planning tasks have been perfected, along with a highly developed set of standards, to the point where all IHI managers, foremen: assistant foremen and workers are intimately familiar with them and rely exclusively on the data and information thus developed. Each manager, foreman and assistant forman has precise and highly detailed guidance data for each work task assigned to him. All detailed planning and schedule data (developed in its final form by the Engineering and Planning Staffs attached to each workshop) are based on the studies and the overall planning for fabrication and ship construction accomplished by Accuracy Control groups. As the work becomes further refined and scheduled, Accuracy Control concepts are translated to these lower T“evels of detail until finally the entire ship construction process becomes a totally defined system of fabrication sequence and methods, of unit construction and outfitting, and of module erection and finishing. This deductive planning method proceeds from the highest to the lowest levels of work all based on the objective of keeping the highest degree of accuracy possible at each stage of production.

With all of this planning and scheduling data precisely developed, managers, foremen and assistant foremen have little to do except to execute the work according to the plan. Their attention can be properly placed on the optimum positioning of material (within a work station), effective application of personnel, and on schedules and work quality. Unlike their American counterparts they are able to place their emphasis on getting the work accomplished well and on schedule rather than on an exorbitant paperwork load, committee action, and “brush fires” usually related to e’rrors in design, fabrication or assembly, or to “up-stream” or “down-stream” schedule slippages.

Accuracy Control within IHI is the bonding agent that holds the system together. It is the guiding principle that provides all planning, design and production functions with the basis and the goal for their various activities. It is the guiding policy that gives form to the system and makes it comprehensible to the people who operate it.

3.6 EFFCT OF ACCURACY CONTROL ON” PRODUCTIVITY

The development of the Accuracy Control concept within IHI has superseded and obviated any necessity for a “Quality Assurance” function. In fact, the combined Accuracy Control and Quality Control system is Quality

Assurance at IHI. The surprising aspect to this fact is that Accuracy Control is in reality a production planning and control process. Throughout the Accuracy Control activity the intent is to thoroughly and properly plan each production process on each component, subassembly and assembly . to obtain the highest possible accuracy. This activity, being fragmented into four separate groups, occurs simultaneously with all other planning and is not separately identifiable from any other aspect of production planning. This may explain the effectiveness of the system and the matter-of-fact approach to this important activity exhibited in the IHI shipyards.

It is interesting to note that in the IHI system, Accuracy Control is the method or means utilized not only to achieve high product quality but also the greatest productivity. These two objectives are achieved simultaneously and automatically. The "before-the-fact" planning accomplished by Accuracy Control establishes the basis for all subsequent planning and the "after-the-fact" measurement, data analysis and correction of methods, sequences and processes serve to perfect not only the planning but the production process itself. This continual improvement of planning data and production processes results in a perpetual refinement of production techniques and a concomitant increase in productivity. Product quality in this scheme is almost a by-product of this continual improvement cycle.

The highly perfected prodcution system of"IHI contains-all of the requisite functions to produce ships in an amazingly short time and at one-third to one-half the cost of U.S. yards. There are several reasons why this is possible but three of the principal reasons are: people, procedures and facilities. In order to understand the effect of Accuracy Control on the IHI system it is necessary to examine each of these elements individually.

3.6.1 Personnel

The effects of the Accuracy Control concept on people vary according to organizational level. The preceding paragraphs spoke to the use of Accuracy Control as a management philosophy and it is evident that this philosophy provides a sound basis for upper and middle management performance. The concept of Accuracy Control has been instituted as a policy to achieve the objective of delivering quality products that "will benefit the customer in the long run." This stated objective has provided shipyard managers with a clear doctrine of corporate aims and management requirements. The translation of this policy into pragmatic methods became, the objective of all IHI management. Once developed these methods were adopted throughout IHI and became the standard practice in all of its shipyards.

Managenmt in the IHI yards has become greatly simplified through the adoption of this standardized approach. Of course, Accuracy Control is only one part of the overall system employed by the IHI yards. However, it is the underpinning of the total production system and more than any other single factor has determined the direction and continuity of the system as it evolved from its inception to the present day.

Presently there is one and only one system for the execution of a shipbuilding contract within IHI (with the possible exception of Naval vessels). All ship contracts are planned and executed in the same manner time after time. Although the same vagaries that affect American yards beset the IHI yards and cause some realignments or organizational changes, the basic system remains the same. In a situation such as this, and especially given the longevity of the IHI workforces (approximately 15 years average Iorigevity in AIOI and HIRE shipyards) every manager and worker becomes so thoroughly knowledgeable and aligned with the system that every job is carried out routinely and with great precision.

Managers at all levels know exactly what has to be done, when, and with what facilities and procedures. Only major exceptions cause any redirection of the established routine and these exceptions are generally not allowed to happen. As mentioned previously, managers are, under this system, free to accomplish their assigned work and to resolve problems among themselves at the lowest level practicable. Interference with their assigned work is a rarity mainly because interference is unnecessary and because all management and workers are aware and in support of the stringent schedules planned for each ship. These schedules are also a part of each worker's, each Assistant Foreman's, and each Foreman's concern with Accuracy and Quality Control. Obviously only superb workmanship can be tolerated in a system geared to hour-by-hour schedules.

On the worker level, Accuracy Control manifests itself in the personal pride each worker takes in his job and his work. As mentioned in the section on Quality Control, each welder signs his work upon completion and is therefore readily identifiable to his Assistant Foreman and to other members of his work group. Fitters are similarly identified through their particular assignment to one area and a specific job. This pride in workmanship is augmented by the fact that each worker is responsible for correcting any of his work found to be discrepant thereby hindering his and his work group's schedule performance. In both regards it is far less disagreeable to perform his work excellently the first time around. Here again because of the high longevity of the worforce the majority of workers are at optimum levels of performance and are maintained at this point by continuing education and training and by the purposeful utilization of personnel in specific jobs and locations.

This clear and precisely deyeloped system seemingly motivates people to increasingly higher work objectives. For example, the KURE shipyard routinely acquires an average of 3000 production improvement suggestions from workers per month. Many of these suggestions are adopted, especially where a benefit to safety, quality or"production efficiency can be seen. Personnel making suggestions that are adopted by the shipyard are given a token award which is generally saved in a group fund for an eventual group party.

The effect of this system on people at all levels of the organization can be seen to be far reaching. Although very little mention of Accuracy Control was made during the LSCo. visits to the IHI shipyards, it was apparent that the concept and its application has become indigenous to the work habits and the routine of the workforce. More obvious during these visits was the emphasis placed on Quality Control but only because discrete functions and organizations are easier to explain than underlying concepts.

3.6.2 Procedures

In the area of procedures (or practices) Accuracy Control is swell understood, if not well defined, aspect of every production function. As explained above the system has been learned over a long period of time by personnel having high longevity with both the system and the shipyard to a point where the concept of Accuracy Control and its application are taken for granted as part of the standard process for producing a ship. Formalized procedures are available but almost never used. It is not necessary for most IHI managers and workers to rely on written instructions other than the current planning and scheduling data relevant to each ship.

3.6.3 Facilities

Supplementing the knowledge of the system and the requirement for accuracy in each phase' of production are the highly perfected facilities which provide the means for the workforce to accomplish their work with all necessary tools, jigs and fixtures, light and heavy lifting equipment, and machines. In this regard, Accuracy Standards have been established for every job and machine operating manuals have been prepared by Accuracy Control groups. Complete sets of templates and measuring devices are present in every area of fabrication, assembly and erection. It is difficult, if not impossible, to differentiate between working tools and the tools used for Accuracy Control. This is another indication of the pervasive nature of the Accuracy Control concept throughout the production process.

As in the case of methods or technique improvement there is an attempt to continually perfect facilities and their utilization. Although the express purpose of this facilities improvement may not be accuracy control, any improvement can always ultimately be seen to benefit the quality of the product. For example, many facility improvements are made on the basis of enhancing worker safety and, of course, personnel safety is an overriding and valid concern for any yard. However, IHI is well aware that not only does worker productivity increase in a safe environment but so does quality. This is'an underlying but real consideration in every area of worker welfare. In AIOI shipyard, analyses have proven that work quality diminishes if employees have either a work-related or a personal problem. Therefore, every effort is made by management to reduce individual problems both at work and, if possible, at home.

Facilities are also viewed from the standpoint of esthetics and of providing a satisfactory working environment for all personnel. Green areas are provided wherever space allows (the design of the CHITA shipyard where abundant space allowed large areas for lawn and trees is the best example of this concern). Fish ponds and smoking areas, usually with some kind of green plants, are provided throughout the shipyards. A heavy emphasis on cleanliness in all work areas is continually stressed by management and work groups. Noise has been substantially reduced by the elimination of high noise machines such as chippers and even by replacing the traditional work whistle with chimes. These aspects of facility attractiveness and desirability directly contribute to worker comfort and welfare and ultimately provide a concomitant improvement, or at least the continued maintenance of high productivity and quality production.

3.6.4 Costs

Naturally, all of this affects costs. The Accuracy Control concept and the highly perfected system that has resulted from it, yield cost benefits from every aspect from the use of the standardized approach utilized in every IHI shipyard to the continual production improvement suggestions put forward by individual workers. Also, because of the high degree of perfection achieved in the IHI shipyard system cost estimating and cost control are reduced to a very finite and predictable science. Costs can be realistically estimated from the wealth of returned cost data from prior ship contracts and cost control can be stringently applied to each operation, each work group, each department and each construction phase. The application of Accuracy Control to the production processes and the resultant quality "consciousness" engendered in all worker and management personnel makes possible the establishment of rigid but very realistic schedules, manpower requirements and facility usage requirements for the produciton of each type of ship. Costs based on these established factors are readily predicable and manageable, and generally result in the construction of each vessel within the cost parameters established for it.

As with most other functions in the IHI shipyards cost accounting is a highly perfected yet relatively traditional function. However, because of the consistent nature of the overall shipyard routine this function is somewhat simpler than that enjoyed by American yards. In IHI the system itself is self-regulating and once plans and schedules for a given ship are firmly set there is little deviation from plan. Hence, cost control and accounting are effected easily from the outset of the detail design/ production program. Several factors influence the ease with which cost control is accomplished in the IHI yards among which is the organization of the production system itself. However, as mentioned several times previously, the base of the production system is the Accuracy Control concept and it is this base that enables the clear definition of the elements of cost - schedules, manpower and facilities.

3.7 THE IMPLEMENTATION OF ACCURACY CONTROL WITHIN LIVINGSTON

Based on Livingston's study of the IHI Accuracy Control concept a decision was made to institute Accuracy Control on the five-ship bulker program to test the merits of the concept within a U.S. shipyard. Two people were designated in the Quality Assurace Department to begin the implementation of the Accuracy Control function. This action was taken in April of 1979.

The initial activities of the Livingston personnel assigned to the Accuracy Control group was to formulate an Accuracy Control plan that was adequate for the bulker program, recognizing that the program was already well underway and that the Accuracy Control function was still a trial activity. The results of this trial would remeasured at a point in the program where the effectiveness of the activity could be evaluated. The plan was established with the assistance of on-site IHI personnel and initially consisted of virtually everything that was performed by Accuracy Control Engineers at the IHI shipyards. After study of the plan it was evident that: 1) the plan must be modified to a more realistic scope and 2) the Accuracy Control staff would have to be increased to accomplish even a reduced scope of activity.

In mid-June the Livingston scope of Accuracy Control activity was redefined as a Planning function and a'Field activity and the Accuracy Control Commiittee was permanently established. The Accuracy Control Planning function-now comprises the following activities: ,

1. Definition of Vital Points - the vital points for maintaining high accuracy are defined on each unit of the bulker.
2. Definition of Vital Dimensions - the vital dimensions on each unit are determined and recorded.
3. Preparation of Check Sheets - Using the above data, check sheets are prepared for each unit that include information on the type of measurement to be taken, ° when, how often, and how many measurements are required.

°After completion of the planning for a series of units, the check sheets are presented to the Accuracy Control Committee for review and approval. Upon approval, the check sheets are issued to Production and to the Quality Assurance personnel responsible for actual measurement.

The Field activity of the Accuracy Control Group consists of:

1. Checking of Templates - an Accuracy Control member checks all mold loft templates for conformance to

working drawings;

2. Checking of Layouts - an Accuracy Control member checks all plates for layout prior to burning. All layouts are accepted or rejected by Accuracy Control. Rejected plates are corrected and then rechecked by Accuracy Control. After burning, an Accuracy Control member spot checks plates to assure burning accuracy.
3. Checking of Sub-assembly - Accuracy Control members coordinate and assist Production and Quality Control personnel in the measurement of all units for twist, level, length, width and frame spacing prior to turn-over for joining with bottom plates.
4. Checking of Assembly- Assembled units are checked for level, twist, length, width, edge alignment and any other requirements specified in the Check Sheets. Accuracy Control members coordinate and assist Quality Control personnel in the measurement of these units.
5. Checking of Erected Units - At erection, units are checked for positioning, alignment, level, center-line, relativity, length and width. As above, Accuracy Control members assist in these measurements.

At each stage of measurement, actual data are recorded, information is fed back to Engineering, Mold Loft, Quality Assurance groups, Production Planning and Control; and Production Department. This information feed-back has already led to the refinement of working drawings, production methods and work sequencing.

In the event a major out-of-tolerance condition is identified during any of the above measurements, the Accuracy Control Committee is convened and appropriate personnel assigned to:

1. determine the cause of the error;
2. determine the fix for the unit out-of-tolerance
3. determine and accomplish the required action to prevent recurrence of the error on subsequent units.

Figure 3-8 illustrates the functions and activities of the Accuracy Control Group as initially instituted at Livingston. Figures 3-3 through 3-6, presented earlier, provide examples of the Check Sheets currently in use.

In July 1979 a Policy and a Standard Procedure for the Accuracy Control function was prepared and approved, formally establishing the function within the company. Also at that time, the Accuracy Control Committee was formally established consisting of the following members:

Accuracy Control Group (one member serving as chairman)

Production Control Representative

Industrial Engineering Representative

Engineering Representative

Production Personnel (as applicable to the action undertaken by the committee)

Two IHI Engineers knowledgeable in steelwork and Accuracy Control methods and procedures

Initial activities of the Livingston Accuracy Control group immediately obtained results both in providing guidance (through the issuance of unit check sheets) to Production personnel and in discovering out-of-tolerance conditions which were corrected prior to movement of the units and subsequent

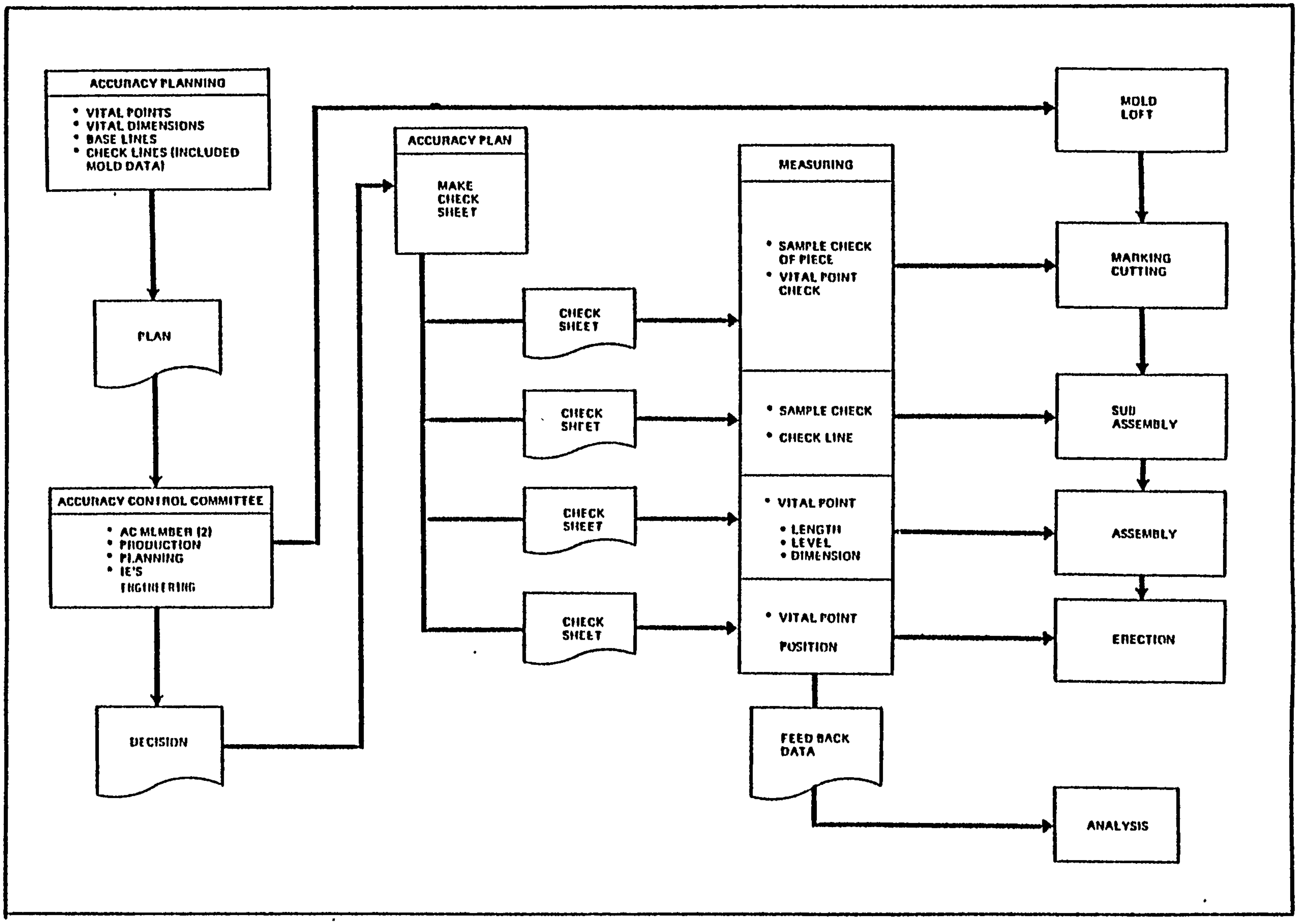


Figure 3-8 Livingston Shipbuilding Company Accuracy Control

major re-work in a "down-stream" position. A major portion of the Accuracy Control effort is the education and training of production personnel who are unfamiliar with the objectives and activities of Accuracy Control. How-ever, in the majority of cases this is being accomplished expeditiously and with good cooperation from the production groups.

In August 1979, two additional personnel were authorized for the Accuracy Control Group and in consonance with other Quality Assurance personnel the Accuracy Control field activities are directly contributing to the higher quality of current production work, and preventing high rates of re-work and premature movement of out-of-tolerance units from work stations. As yet no complete assessment of cost savings from this activity can be made. However, it is clear that Accuracy Control field activity is significantly improving product quality.

3.8 THE ACCURACY CONTROL CONCEPT APPLIED TO AMERICAN SHIPYARDS

The Accuracy Control concept as practiced by the IHI shipyards is more than a simple quality assurance function. From the preceding discussion it can be seen that the Accuracy Control concept is in reality an entire production philosophy applied throughout the IHI organization. This report deals specifically with its development and application in the IHI shipyards but it is this same concept that is employed throughout IHI companies regardless of their product line. In IHI it has taken many years for this concept to develop in its full dimension and for its translation into pragmatic methods which can be implemented into an on-going production system. The IHI yards have been involved in the development of this concept from its inception and many management and worker personnel have been a part of the evolution of Accuracy Control, from concept to working practice, literally from the day they began their careers with IHI.

The concept of Accuracy Control, although it can be considered as simply another manufacturing methodology, fits extremely well with the underlying Japanese social and religious philosophies with their emphasis on group rather than individual consciousness, their overriding concern with personal welfare in terms of safety and fair treatment, and their inherent ethics.

Also, the concept of Accuracy Control and the system it has engendered, fits with the traditional lifestyle of most Japanese. The highly developed skills required to perfect and continue routine operation of the IHI shipyard system came as much from the fact that the workforce is highly stable and of long tneure as from any other single factor. Population mobility is far less than most modern industrialized countries and almost diametrically opposite that of the United States. Japanese industrial workers do not readily change jobs from one company to another. In fact, a “life-time” contract is granted to each employee in IHI which guarantees the employee’s job throughout his working career. This guarantee, together with bonus plans and a host of other personnel benefits, provides sufficient incentive to keeptmost employees with the company for their entire working life; Additionally, organizational mobility is far less than in American firms. This aspect is probably directly traceable to the mobility of the population in that a stable workforce does not allow as many recurring job openings.

All of these factors apply when considering the institution of any new concept such as Accuracy Control to an American firm. Of basic concern is the fact that the concept is a very different way of thinking. American industrial and business practices have evolved into a progressively more complex system since the turn of the century. The basic “free enterprise system” and the many separate organizations concerned with this “system”, i.e. corporations, labor unions, government, etc., have all developed into a defined pattern of interaction which ultimately determines the thinking processes used in daily business activity. In many ways American industry is constrained by this established pattern and by the realities of these business relationships integral to the American socio-economic structure. This structure is far different from that of the Japanese and to attempt to totally adopt this Japanese concept in an American shipyard could only result in frustration. However, some adaptation of the concept is possible and, if properly instituted, can result in significant benefits.

Obviously, given the variables attendant to most U.S. shipyards (i.e. an unstable, largely unskilled, and highly mobile workforce; the traditional work practices and ethics of these workforces; and the continuing impact of government and labor unions) the Accuracy Control concept would require drastic “tailoring” to fit these different circumstances. ” One of the principal obstacles to even beginning the institution of the concept is the fact that most American firms are “vertically” organized into discrete and wholly separate operational elements. For example, Quality Assurance in American yards is a separate organization with a defined charter and standard operating procedures governing its authority and responsibilities. It extends laterally across the entire company organization to accomplish these responsibilities but always operating as a clearly separate organization performing a clearly separate function. Likewise production, design, production planning and control, material control, etc., are all organized or “compartmentalized” into discrete and clearly defined organizational elements.

The Japanese shipyard organization is far less rigidly structured and in practice works as an amorphous whole. The IHI organization, although presented graphically in traditional "Organization Chart" form, really works laterally across the entire shipbuilding process. The distribution of engineering personnel in the mold loft, the Production Planning & Engineering groups in each workshop, and in Material Control and Quality Control indicates this lateral approach. Further, production planning (with its component of Accuracy Control) is not centrally organized or controlled. Rather, it is fragmented inter the four major areas of design and construction with each group accomplishing and coordinating the detail planning necessary for each area. Similarly, production manning and scheduling, and material handling is extended across several groups operating under the three workshops. These groups report to the superintendent of the workshop in which they are engaged. They do not belong to a separate central organization established to provide this service to the workshops. This spread of engineering personnel in many activities throughout the shipyard provides an active production environment where knowledgeable personnel constantly-interface to resolve concflicts of priority, schedule, process, design, or any other encumbrance to production objectives. Understanding this type of lateral organizational interaction must be the first priority if any employment of the Accuracy Control system is to be attempted. Figure 3-9 depicts this lateral movement of functions and activities across the IHI system.

American yards can profit to some degree from the adoption of any of the several aspects of Accuracy Control. The entire system need not be implemented in order to yield benefits to a shipyard. Livingston Shipbuilding has chosen to proceed on a step-by-step program toward the implementation

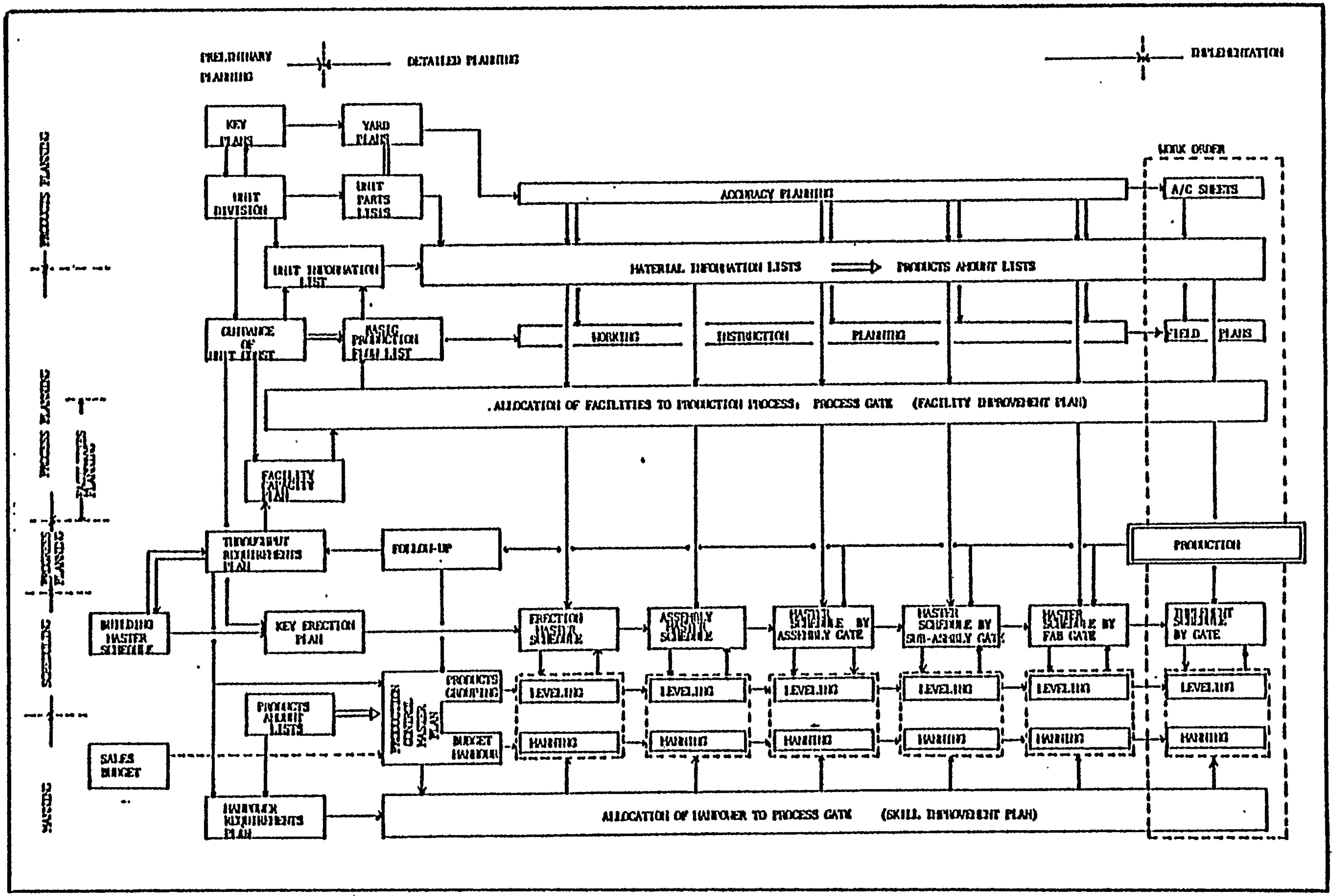


FIGURE 3-9 TOTAL PLANNING FLOW FOR HULL PRODUCTION

of as much of the Accuracy Control concept as appears warranted, and the company has gained some immediate benefits from this action (e.g. in the improvement of accuracy on hull units, prevention of re-work, prevention of movement of out-of-tolerance assemblies).

Essentially, there are three major parts of Accuracy Control that can be addressed as a possibility for American shipyard implementation. The concept can be implemented as an extension of the existing Quality Assurance/ Quality Control activity (this is what has occurred at Livingston). It can also be implemented as a production planning process, (although this would perhaps be the most difficult of the three,) or as a product improvement process. Of course, the most desirable is the implementation of the entire concept which is also possible in an American yard. This would encompass all of the above elements but would necessarily require adaptation to the ‘ conditions and circumstances of the individual yard.

As an extension of an existing Quality Assurance function, the institution of an Accuracy Control group can contribute significantly toward an increase in product quality and in productivity. Even if there were no attempt made to accomplish the initial planning actions inherent in the IHI system, the development of Accuracy Check Sheets, the development of measurement devices and techniques and a shift in emphasis toward the maintenance of critical alignment and interface dimensions can have a pronounced effect on product quality. Also, this activity would have tangential effects which would serve to improve productivity. For example, the preparation and issuance of Accuracy Control Check Sheets to the Production operations and to Quality Control will immediately raise the level of “quality consciousness” in those personnel responsible for producing and checking the work. Also, the increased attention to quality, evident by the issuance of the Check Sheets, will cause a greater degree of caution in the performance of work by individual workers.

The "field" activity of an American Accuracy Control group can be equally beneficial in several ways. The measurement of plate layouts, cut plates and completed assemblies can prevent costly mistakes and extensive re-work. It can also prevent movement of pieces, sub-assemblies and assemblies from an area where correction of an error or discrepancy can be readily effected to another area where correction is more difficult, costly or dangerous. Perhaps even more important, an Accuracy Control group can, through feed-back to engineering, mold loft, fab shop or other involved activities, prevent a recurrence of the problem on subsequent units.

The institution of the Accuracy Control concept as a production planning process would undoubtedly require a realignment and reorientation of the existing yard Production Planning and Control function. It is questionable as to. how much of the IHI Accuracy Control Planning function could or should be utilized by American yards. If the entire planning function were instituted it would require considerable reorganization of the existing planning, scheduling and production control system and, as a consequence, an almost total commitment to adopt the entire Accuracy Control concept. As described in paragraph 3.2, this Accuracy Control planning activity begins immediately subsequent to the completion of basic design and develops some very detailed planning for fabrication, assembly and erection. Many different types of activities and skills are blended into this planning function which are presently performed by separate organizations within American firms. Here again it is important to recognize the fact that

Accuracy Control works across the entire shipyard organization and production process and, consequently, is involved in virtually every aspect of ship construction. This single element of Accuracy Control will cause a radical departure from traditional American practice.

Perhaps the simplest adaptation of Accuracy Control would be as a Product Improvement Program. In this application as much eras little of the Accuracy Control concept could be applied as desired. Parts of the planning process could be integrated into the existing production planning and control system just as parts of the quality control process could be assumed by the existing Quality Assurance function. Any number of combinations could be instituted; all of which can positively affect both productivity and product quality.

Basically, the Accuracy Control concept is startlingly simple. ,The basic objective of Accuracy Control is to perfect each production process to,yield the highest accuracy possible in each piece or part undergoing that process. However, the scheme which is developed to achieve that objective, and the application of that scheme, is an extremely difficult prospect especially in an American yard. In the highly developed IHI production system this objective has largely been achieved through the evolution over many years of a dynamic and Self-regulating ship construction process. During this evolution many of the benefits ultimately realized by IHI were unplanned and unanticipated by the developers of the system. This would also probably be the case with American yards choosing to implement part or all of the Accuracy Control concept although, as in the case of IHI, it would surely require many years before such benefits became manifest. Additionally, the benefits attributable to the institution of part or all of the Accuracy Control concept will be difficult to measure. The effect of higher accuracy, although conceptually apparent that it benefits the production process, cannot be easily assessed in terms of cost savings or schedule achievement. Too many factors play a part in the overall production scheme to accurately pinpoints single element as improving or degrading production manhours or material costs.

The attempt to institute 'Accuracy Control in an American yard will necessarily take strong management action. A policy established by the Chief Executive is the initial requirement together with some degree of management training in what is expected and how it is to be Implemented. Impacts on shipyard organization, attitudes and traditional work habits and procedures should be studied and a planned program developed to identify and schedule the implementation effort.

Many technical reports are issued each year describing new and innovative approaches to management, production and the many other functions of industry. Most of these reports deal with the application of these new approaches without much concern for the underlying philosophy which is the necessary foundation for successful implementation. In reports on foreign technology this is a serious oversight.

In American industry foreign concepts such as Accuracy Control, may not be fully applicable nor as successful as that experienced by other cultures. A great many factors may militate against the complete adaptation of Accuracy Control to U.S. shipbuilding practice. However, the basic concept and many of the proven and adaptable parts of this technology can be employed to some degree to improve quality and productivity.

SECTION 4

QUALITY CONTROL

4.1 JAPANESE STANDARDIZATION OF QUALITY CONTROL

In recent years, there has been considerable effort among Japanese shipbuilders to establish shipbuilding standards both in manufactured products and to some degree in the processes that contribute to the quality of those products. During the development of the IHI production system, most of the innovative approaches taken by IHI (in both production and Quality Control) were shared with the rest of the industry and in many cases became the industry standard. Also, due to the overriding concern with product quality and the various systems employed by the shipbuilding industry to assure this . quality both to the customer and to regulatory agencies, an effort to standardize quality control and inspection practices was introduced by Lloyd's Register of Shipping. The system advocated by Lloyd's was based on the IHI Quality Control System.

Essentially, all Japanese shipyards now employ a Quality Assurance system based on three major quality control elements: 1) Steel F1ow; 2) the Organization of Labor; and 3) A List of" Characteristics. These elements function in the Quality Assurance system as follows:

4.1.1 Steel Flow

Generally all shipyards have a steel flow arrangement similar to Figure 4-1. Briefly, this figure indicates the steel in the stockyard, (some Japanese yards carrying only two days supply) then leaving the stockyard for shot blasting and priming, followed by marking. Marking is generally by Electro-Photo Marking (E.P.M.) with the more advanced yards using numerical control.

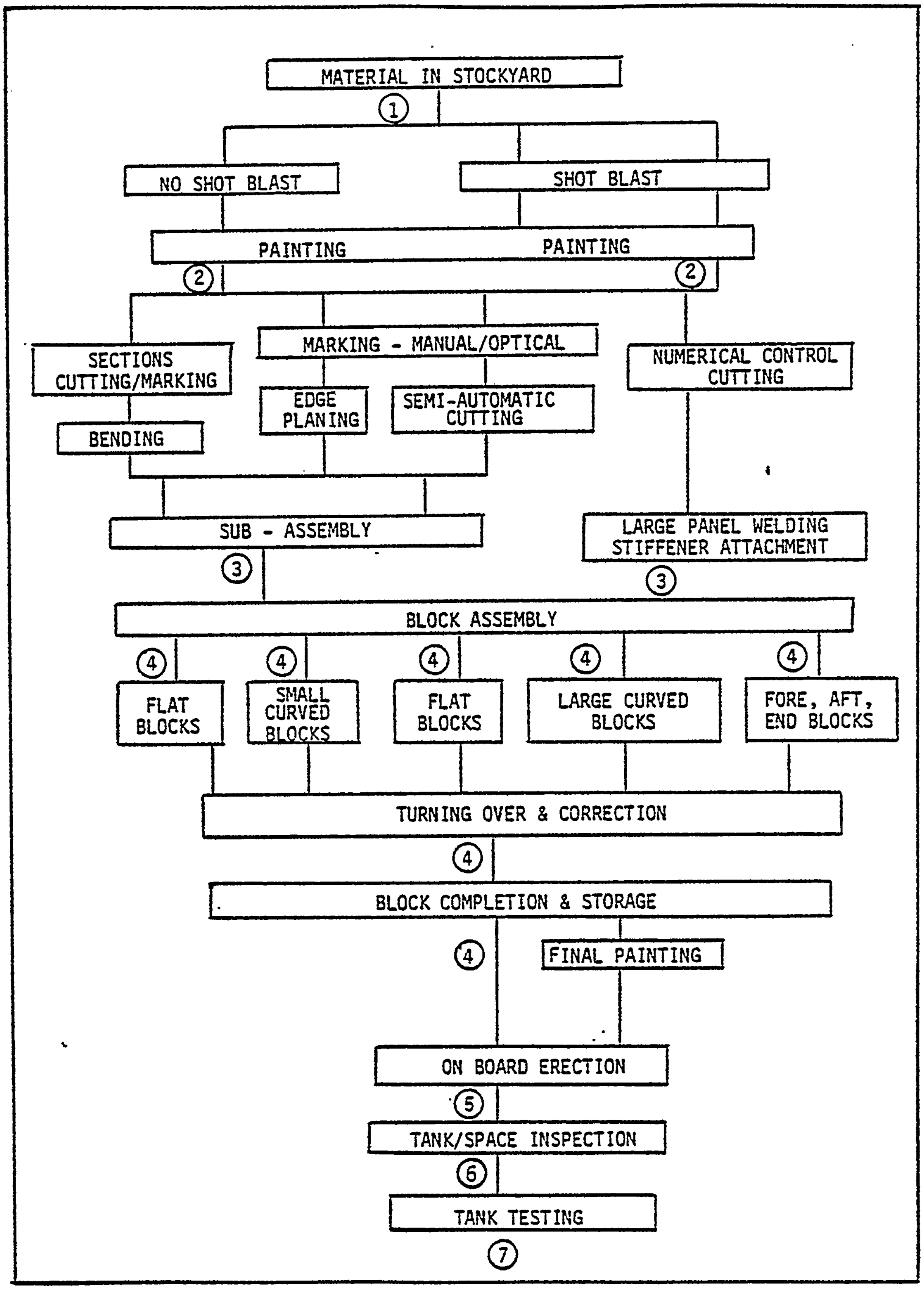


Figure 4-1 STEEL FLOW ARRANGEMENT

After cutting and forming, using automatic or manual methods, edge planing, gas cutting, etc., the steel is then in the form of plates or fabricated pieces. Melding processes, generally gravity for fillet welds and large scale automatic processes for butts, produce panels or sub-assemblies weighing up to 50 tons.

These components are transferred to the assembly shop for block (unit) assembly. Assembly may involve re-positioning and turning of the unit, until the block reaches the end of the assembly shop, in a finished condition. At this point blocks are painted, outfitting items are assembled, and the block prepared for on-board erection after fitting of staging, lifting lugs, etc.

After fitting and adjusting on-board, the erection butts are welded, the tanks/holds, etc., are completed and finally tested.

This procedure varies slightly for each yard, but in general is typical of all yards.

The designated inspection/control stations by most yards are indicated by numbers on the figure which correlate to the following:

1. Th'e identification of steel in stockyard by comparing steel markings against steel order form, mill sheet, cutting plan, computer return, etc.

2. Further confirmation and marking after shot blasting and priming. Between Nos. 2 and 3 stations, the various automated and mechanical processes are periodically checked against fixed standards.

3. When sub-assemblies are completed and are ready to be transferred to the assembly area.

(4) This is a progressive station, commencing with the inspection of the assembled block in a temporary welded condition, periodic welding checks in the various welding positions of the block, and terminating in a finished block inspection.

(5) The block has been erected on-board and the joints (butts) are completed.

(6) The tank, hold, or other spaces are considered complete.

(7) The tank is pressure tested.

4.1.2 The Organization of Labor

In most Japanese shipyards, Quality Control personnel are under the jurisdiction of the Hull Construction Department and final inspections are controlled by an Inspection Section in an administrative department. All members of the Quality Control groups have a definite production commitment and are selected by management.

Initially, each workman has the responsibility of checking his own work. For every eight men (approximately) there is a leader (Assistant Foreman) who checks completed work after the worker's check and any necessary repair. The unit is then independently checked by a Chief Leader or Foreman. There are approximately six leaders per Chief Leader/Foreman. All items are, therefore, double checked before being considered complete by the Hull Construction Department.

In addition to this "self-check" system, a Quality Control group usually exists, which includes highly trained Quality Control specialists together with other personnel from workshops or other concerned departments.

The function of this group is for:

a) checking items which do not lend themselves to a self-check system;

b) trouble shooting;

c) control of subcontracted items (in some yards, this constitutes a large percentage of production);

d) promotion of Quality Control;

e) analysis of information collected from the self-check system; and

f) immediate decisions arising from the above items.

The function of the Inspection Department is primarily the organization of finished inspections, both in the shipyard and at sub-contractor establishments. Upon being advised by production that an item is complete, Inspection Deparment personnel confirm that the item is ready for Owner's and classification inspection and act as liaison to accomplish these inspections.

4.1.3 List of Characteristics

Lists of characteristics, showing all inspection items to be considered, have been complied by most shipyards. These items are listed in **Table 1** below:

TABLE 1

List of Characteristics

Hull Constrtuction	**Helding**
1. Misfitting of Member	1. Weld Fracture
2. Scantling Check	2. Misuse of Electrode
3. Misalignment: - Butts Fillets	3. Welding Omitted
4. Fit-up Gaps: "Butts Fillets Laps	4. Leg Length 5. Undercut
5. Deformation: - Shell1, Deck, Tank ToP Bulkheads Girders, Transverses Floors in D.B. Beam, Stiffeners Brackets House Walls	6. Return Welding 7. Appearance: - Bead Appearance Reinforcement Short Beads Blow Holes
6. Finishing: - Nothches Edge Raughness	8. Surface Finishing: - Removal of Temporary Welding Undercut after Removal of Temporary Welding Gas Notch Arc Strike

These characteristics together with related tolerances and methods of repair were collected from all shipyards, compared and a basic standard developed. The Quality Control Check Sheet developed by IHI (shown in Figure 4-2) is now considered to be the industry standard in Japan.

In summary, there is a pattern of steel flow which is common to most Japanese Yards. Gnerally, there are consistent check (inspection) points in that steel flow and these check points usually employ a double check in production followed by an inspection check upon completion. Also, there is a standard list of characteristics and definitions, tolerance and method of repair to define requirements for quality production and control.

This pattern of steel flow is rigidly controlled to achieve the highest possible quality throughout the fabrication and construction process. In the inspection sequence check stations 1 & 2 are considered as highly sophisticated control checks, run exclusively by the shipyard with only random checking by the surveyor.

The various mechanical preparations between stations 2 & 3 are checked against standrads on a monthly basis by the shipyard and documented on a check sheet filed adjacent to the machine.

At station 3 , the double production check by leader and foreman, followed by Inspection Department check, is begun. Sub-assemblies are checked against the Quality Control check sheet, listing all relevant information. The maximum acceptable tolerances taken from the approved code of practice or standards are also shown, where applicable, on the listing.

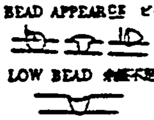
As check 3 is a sub-assembly check, groups of sub-assemblies are

P/E
LOT
W/U

W. Q. C. CHECK SHEET

	SUB ASSEMBLY (小組)
	ASSEMBLY (大組)
	ERECTION (外業)

S.No		BLOCK OR TANK		溶接長 WELD LENGTH	METERS	場所 SHOP	

GRADE 等級	CHECK POINT チェック項目 / CHECKER	作業リーダー LEADER	QC 1	REP 手直し	品質管理班 QC MEMBER	QC 2	REP 手直し	検査担当 INSPECTOR	減点		REP 手直し
A	CRACK 割れ								11×		
	MIS-USE OF ELECTRODE 溶接材料の選定								11×		
	WELD OMITTED 溶接忘れ (300mm 1 POINT)								11×		
B	LEG LENGTH 脚長 0.9L > L1 L: Leg Length on Plan 断面脚長 300mm 1POINT								4×		
	UNDERCUT アンダーカット BUTT IN SKIN & FACE E. IN 6L 区 ≤0.5 300mm 1POINT								4×		
	OTHERS ≤0.8								4×		
	RETURN WELD 角廻し (5 DEFECTS : 1 POINT)								4×		
	BACK GOUGING ウラ堀り										
C	BEAD APPEARCE ビード外観  LOW BEAD 余盛不足 REINFORCEMENT 300mm 1POINT								2×		
	SHORT BEAD MIN.50M.L.T. ショートビード 〃 50M.L. SURFACE ブローホール POROSITY ピンホール 等 5DEFECTS 1POINT								2×		
	スラグ除去								2×		
D	REMOVAL OF TEMP. FITTING & WELD								2×		
	REPAIR OF U CUT AFTER REMOVAL OF TEMP. W. アンダーカットの手直し								2×		
	GAS NOTCH 切込みキズの手直し								4×		
	ARC STRIKE アークストライク								2×		
	OTHER MINOR ITEMS その他 (5 DEFECTS : 1 POINT)								減点小計		

SUMMARY	作業リーダー LEADER	A	B	C	D	品質管理班 QC MEMBER	A	B	C	D	検査 INSPECTOR	A	B	C	D
備考 REMARKS	—DO—					—DO—					作業リーダー LEADER				
											品質管理班 QC MEMBER				
							減点合計				検査 INSPECTOR				
FAT											等級 CLASS				

FIGURE 4-2

A. Q. C. CHECK SHEET

	SUB ASSEMBLY	(内業)
	ASSEMBLY	(大組)
	ERECTION	(外業)

S.No.		BLOCK OR TANK		ブロック重量 BLOCKWEIGHT	TONS	場所 SHOP	

GRADE 等級	CHECK POINT チェック項目 / CHECKER	作業リーダー LEADER	QC 1	REP 手直し	品質管理班 QC MEMBER	QC 2	REP 手直し	検査担当 INSPECTOR	減点係		REP 手直し
A	MISFITTING 誤作、つけ忘れ								11× 4×		
	SCANTLING CHECK 寸法不足								11× 4× 2×		
B	MISALIGNMENT 目ちがい (重要部材 MAIN STR. / その他 OTHERS) BUTT つき合せ: < 0.15t / < 0.2t (MAX. 3)								4×		
	FILLET すみ肉: < t/3 / < t/2								4×		
	GAP ギャップ BUTT: G≤5; 5 < G ≤ t/2 ウラ当て; t/2 < G < t ウラ当てし開先整形								4×		
	FILL: G≤3 増脚長; 3<G<5 面取りのみ; 5<G<t ウラ当て								4×		
	DEFORMATION 歪 (TANK部 / F & A) IN SHELL 外板 ≤6 ≤7 DECK デッキ ≤6 ≤8 TANK TOP タンクトップ ≤8								4×		
	BHD 隔壁 ≤8 GIRD. TR トランス ≤8								4×		
C	GAP ギャップ LAP(重ね) ≤3								4×		
	DEFORMATION 歪 IN FL. & G. IN DB 二重底内フロアガーダー ≤8 BKT ≤2t/3								2×		
	STIFF & BEAM HOUSE WALL ≤8								2×		
	FCPLの折れ曲き 4.5mm/100mm 部材の倒れ 5°								2×		
D	NOTCH ノッチ EDGE ROUGHNESS ガスキズ								4× 2×		
	OTHER MINOR ITEM その他 (5 DEFECTS : 1 POINT)								減点小計		

SUMMARY	作業リーダー LEADER	A	B	C	D	品質管理班 QC MEMBER	A	B	C	D	検査 INSPECTOR	A	B	C	D
備考 REMARKS	—DO—					—DO—					作業リーダー LEADER	月 日		月 日	
											品質管理班 QC MEMBER				
											検査 INSPECTOR				
											船級 CLASS				

FIGURE 4-2

checked on the same sheet rather than individually, particularly if all sub-assemblies for one block are gathered together at the sub-assembly stage.

At block assembly stations (4) a progressive check is made on the complete block once it is tack welded in an assembled condition. A Quality Control check sheet is then completed and attached to the unit.

Once any area on a unit is completely welded, the welding check sheet (see Figure 4-2) listing all welding characteristics is issued and marked. At the finished block inspection both lists must be completed, double checked and signed.

At this point the Inspection Department surveys the hull module, (in addition to the previous checks) using the same sheet to indicate their recommendations. After repair.of any defects, the sheet then forms the basis of the report to the regulatory agency and to Owners.

After the block has been positioned on-board, a hull construction check sheet is issued and relevant items checked. After welding, both the welding and the hull construction check sheets are completed.

At the time of the internal inspection of tanks/holds, all erection butts in that space and their check sheets are examined by Inspection Department personnel in a similar fashion to the finished block inspection. This inspection is then reported to the regulatory agency and the Owner.

The Surveyor (regulatory agency] is then in possession of complete reports from three different stages in the ship's construction (i.e. sub-assembly, block assembly, and on-board completion) at three different labor levels (leader, foreman, inspector]. On the basis of these data the Surveyor performs a quality assessment which entails the following:

Initially the Surveyor will classify any defective characteristics into grades. This grade is based upon the seriousness of the defect coupled with the need for instant action to prevent recurrence of the defect at its source. Four grades, A, B, C, and D, are used in this classification.

Grade A defects are considered to be the most serious defects found on inspection while Grade D's are concerned with the finished appearance of the unit. Grades B and C are divided upon consideration of severity and comparison between mechanical/manual operations.

Using the characteristics shown on the hull construction and welding check sheets, grading is accomplished as follows in **Table 2:**

TABLE 2

GRADING OF DISCREPANCIES

	Hull Construction	Welding
Grade A	Misfitting of Member Scantling Check	Weld Fracture Misuse of Electrode Welding Omitted
Grade B	Misalignment: - Butts Fillets Fit-up Gaps: - Butts Fillets Deformation: - Shell, Deck & Tank Top Bulkhead Girders & Transverses	Leg Length Undercut Return Welds
Grade C	Fit-up Gaps: - Laps Deformation: - Floors in D.B. Beams & Stiffeners Brackets House Walls	Bead Appearance: - Low Beads Excessive Reinforcement Short Beads (H.T.) Blow Holds
Grade D	Finishing: - Notches Edge Roughness	Surface Finishing: - Removal of Temp. Welding Repair of Undercut after Removal of Temp. Welding Gas Notch

With each grade there is an action level, i.e. when the number of defects of this Grade on a unit reach a pre-determined level, a report must be made by the Quality Control group, the cause investigated and the method of repair decided.

Based on experience, action levels were defined as follows in Table 3:

TABLE 3

ACTION LEVELS

Grade	Hull Construction (No. of Occurances)	Welding (No. of Occurances)
A	1	2
B	3	6
c	3	6
D	4	10

These levels, however, are individually open to decision by the Quality Control group, taking into consideration the complexity of the block, critical areas, access difficulty for working, type of ship, Owners opinions, etc.

All defect grading must be inserted on the check sheet when each unit is considered complete by the leader, foreman and inspector. The finished report will, therefore, show all defects in an A, B, C, D breakdown.

This information is then summarized using sumnary check sheets (same as Figure 4-2), one for hull construction and one for welding. These sheets are prepared by the shipyard from their own documents and endorsed by the surveyor.

Grading results are then forwarded to a central office, providing an identification of each item (SUB-ASSEMBLY, UNIT, COMPARTMENT) and the number of A, B, C, D defects for each, on a weekly.basis. If considered necessary, the A, B, C, D grades can be broken down into individual defects for analysis.

With the introduction of data-processing equipment, the large amounts of data which must be recorded, processed, and analyzed, can be put into comprehensive reports which point out those areas where corrective action is most urgently needed.

4.2 <u>IHI QUALITY CONTROL</u>

Quality Control is the "watchdog" in the IHI Quality Assurance system. This organization functions throughout the design and production process both before and after the fact. Quality Control's role begins in the design process where quality requirements are input to the design engineers on an overall and a drawing-by-drawing basis. All drawings used for outside procurement are checked by Quality Control prior to release. Another aspect of Quality Control in the design process is in the development of quality specification requirements for purchased material and in the development of Accuracy Control Check Sheets for the components and units built by the shipyard.

The responsibilities of Quality Control in the production process range throughout the typical functions of on-site vendor inspections, receiving inspection, in-process inspections, component and system testing, NDT inspections, and dock-side, builder and final acceptance trials. Throughout the process Quality Control establishes the requirements, receives and records inspection data (whether or not performed by a Quality Control inspector] and actively monitors the quality of workmanship and product at each stage of production.

Because of the reliance placed on the individual worker, the group checkers and the assistant foremen, the Japanese Quality Control activity is more one of quality management. The Quality Control group establishes quality requirements for each product, educates and trains foremen, assistant foremen and workers in the accomplishment of the required quality, collects applicable data for analysis and for verification of work to quality standards and customer specifications, and generally monitors the production process to assure that established requirements are being met. In the performance of these duties Quality Control representatives play an important part in virtually all aspects of design, production planning and the production methods utilized for ship fabrication and construction.

One of the principal functions of the Quality Control activity is to assure the safety and well being of the individual workers. The Japanese recognize the importance of these personnel-oriented aspects of production. Their concern is based on the established fact that poor quality results from unsafe working conditions and/or unhappy workers. Therefore, Quality Control involves itself in all decisions concerning this type of personnel relations.

4.2.1 Quality Control Organization

The IHI Quality Control Department (Ships Group) reports directly to the General Superintendent of Shipbuilding and is organized into five major sections as shown in Figure 4-3. Some 43 personnel were active in the Aioi Shipyard Quality Control group on July 1, 1979 not including the department manager.

The various inspection activities are organized by traditional ship breakdown into hull, electrical, mechanical (engine) and into an administrative function and a post-delivery (service) function.

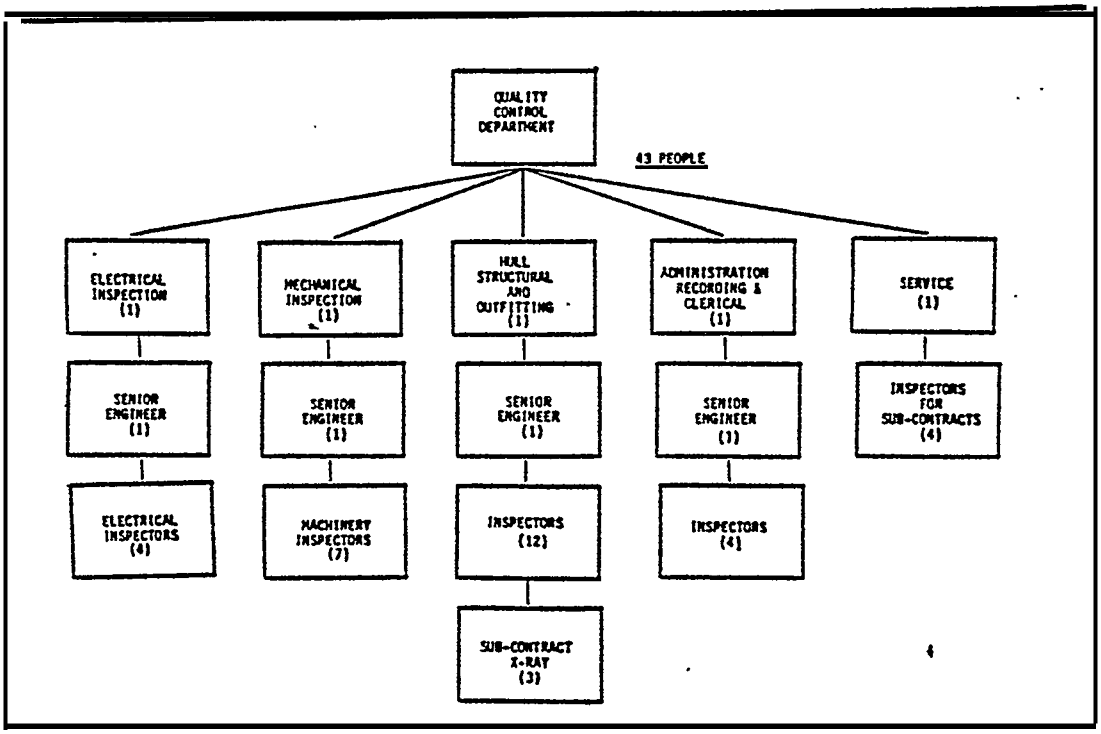


Figure 4-3

The published responsibilities for the Quality Control Ships Group collectively are as follows:

1) Planning and control of ship inspection schedules.
2) Recording of inspection results.
3) Recording of information for classification surveyors.
4) Issuance of inspection applications to customer inspectors and surveyors.
5) Preparation of inspection standards.
6) Collection of data and study of technical problems on delivered ships.
7) Control and dispatch of guarantee engineers and/or service engineers to delivered ships.

4.3 QUALITY CONTROL PROCEDURE AND DATA FLOW

The Quality Control system used in IHI basically follows the flow diagram shown in Figure 4-4. This figure shows the various activities and feed-back loops inherent in the IHI Quality Control process. Figures 4-5 through 4-9 provide greater detail of the Quality Control activities related to specific areas of ship construction. Appendices F and G provides an indication of the standards used for inspections and testing throughout the production process. Appendix H provides details of the inspection requirements on the Future 32 Class vessels. Appendix I shows similar requirements used for sea trials for the bulkers. These requirements, established at the outset of a new ship contract, may vary from ship to ship depending on ship type and differing inspection specifications.

The most important procedure used in the IHI Quality Control system is the 3-point inspection system employed to assure the accuracy of the fabricated components and assemblies and the high quality of all weldments throughout the production process. In this regard a single check sheet is used for each unit at each production stage which is signed by the assistant foreman, the group checker and finally by the Quality Control inspector on a number of various conditions which may exist on the work at each work station. One side of the check sheet is used for "Welding" inspections while the reverse side is used for "Acctiracy" inspections, (WQC indicates Welding Quality Control - AQC refers to Accuracy Quality Control). This Check Sheet (see Figure 4-10) is physically attached to the component or unit undergoing fabrication or assembly and is used throughout the inspection process to document deficiencies and corrective action. All deficiencies are corrected by the worker making the error even if the

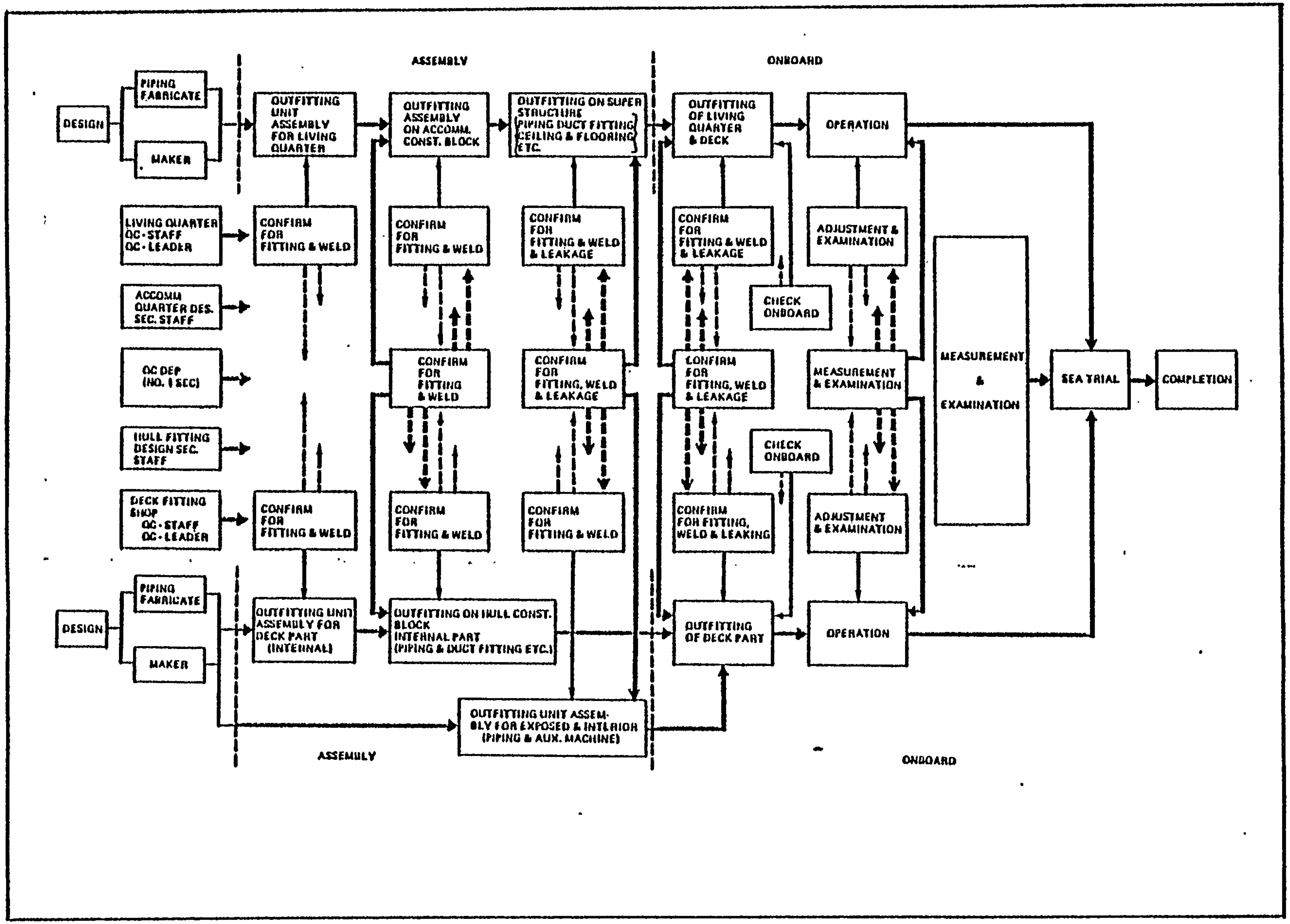


FIGURE 4-6 QUALITY CONTROL FLOW CHART (HULL FITTING) (IHI)

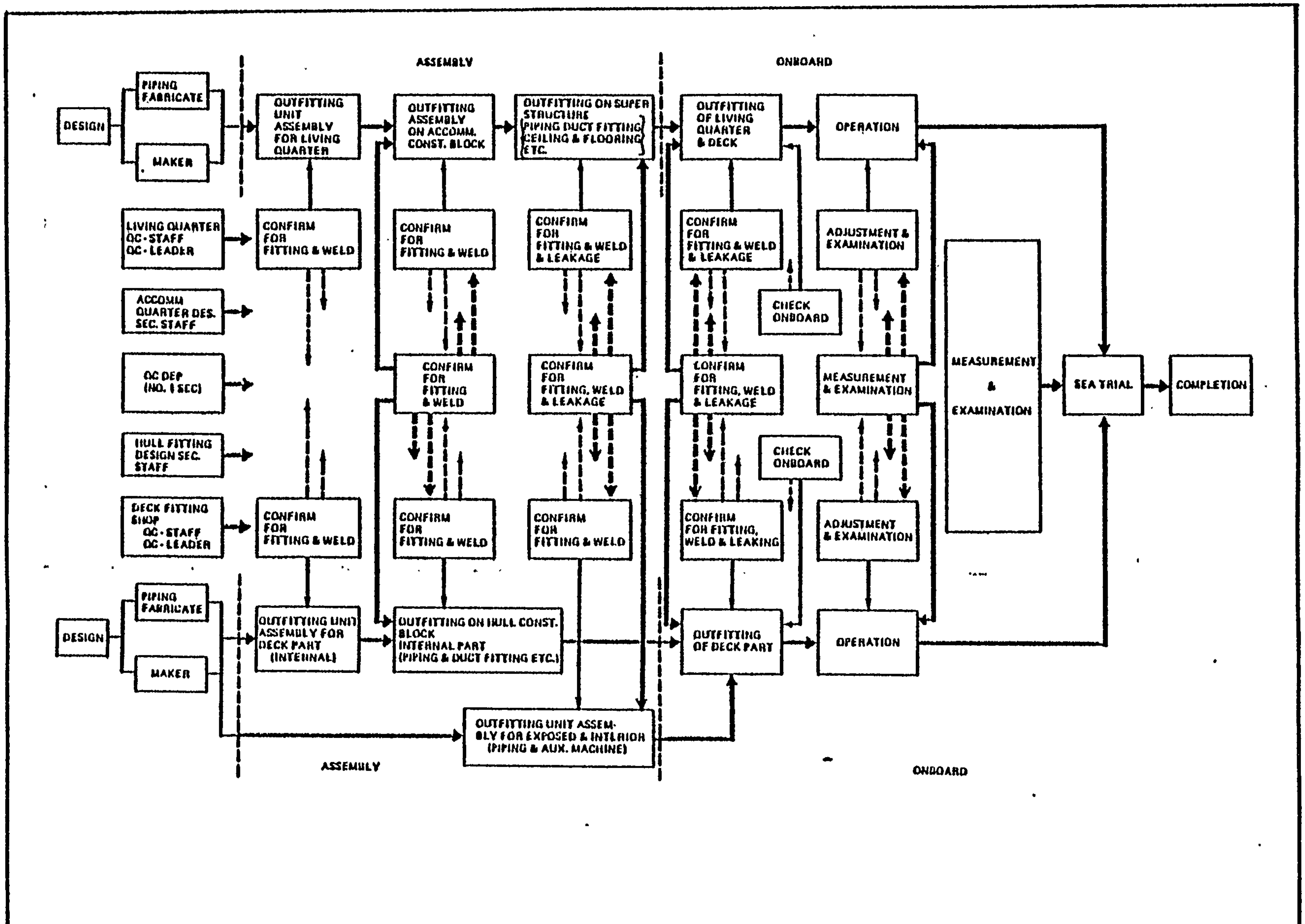


FIGURE 4-6 QUALITY CONTROL FLOW CHART (HULL FITTING) (IHI)

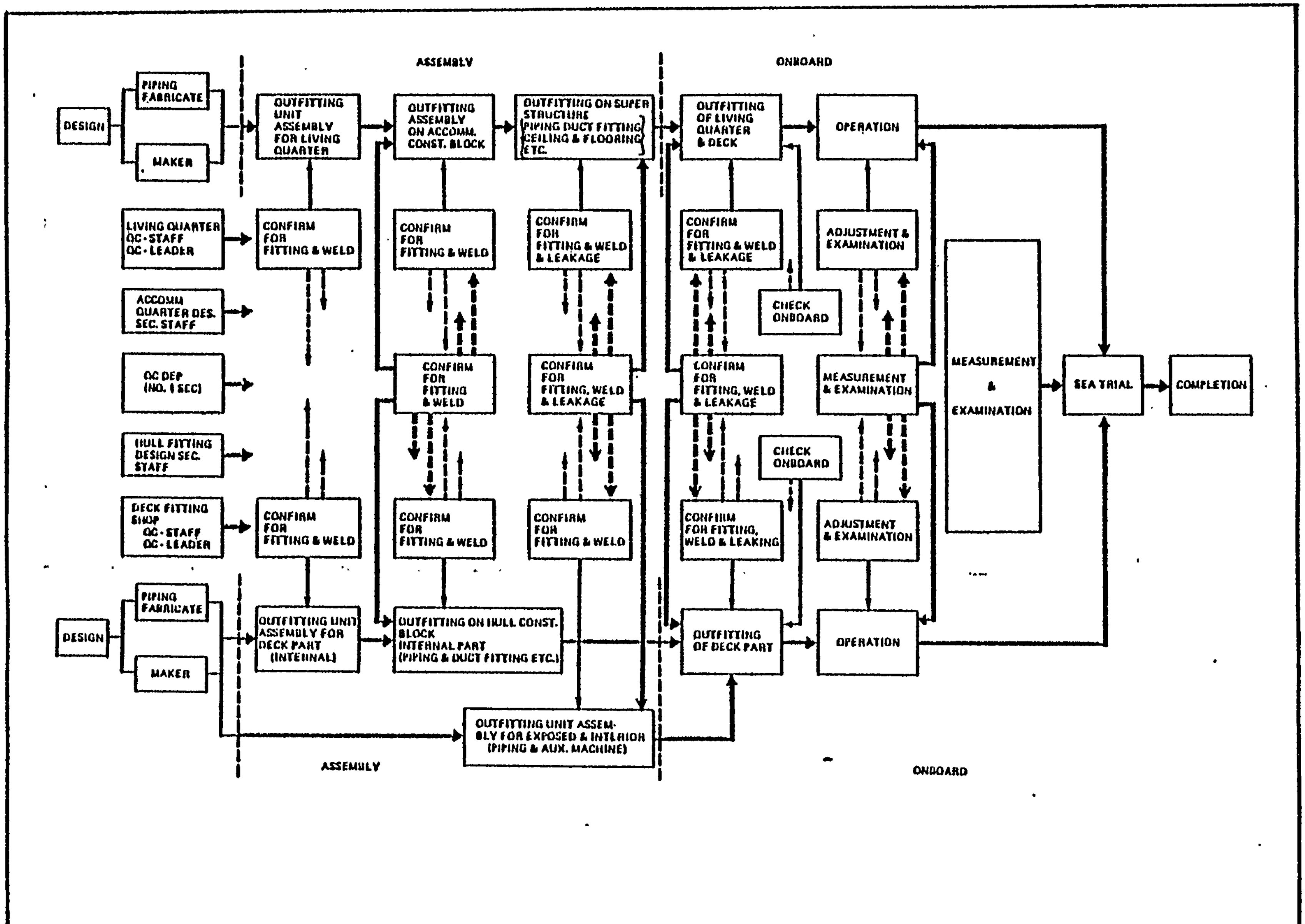


FIGURE 4-6 QUALITY CONTROL FLOW CHART (HULL FITTING) (IHI)

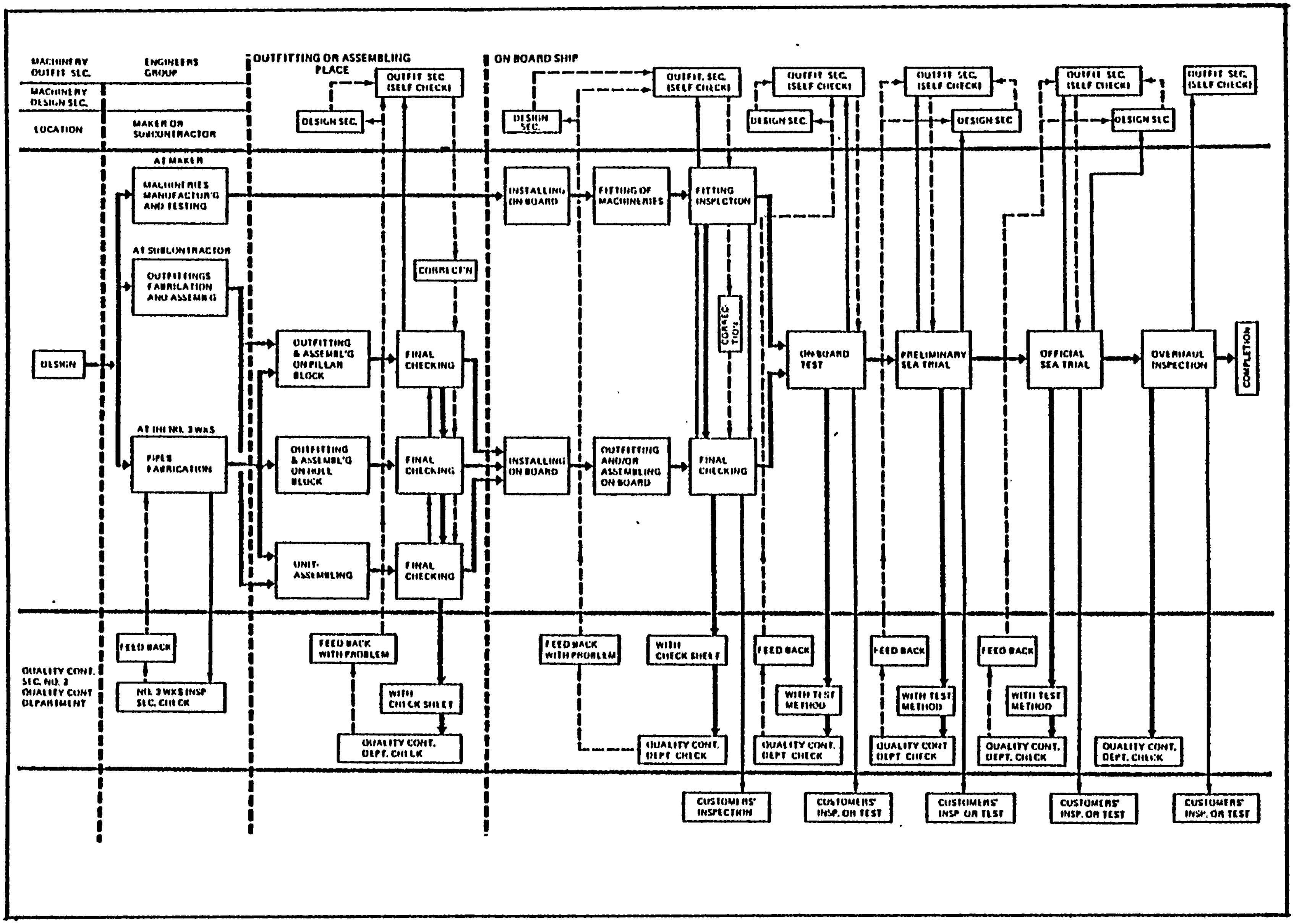


FIGURE 4-7 QUALITY CONTROL FLOW CHART (MAIN ENGINE) (IHI)

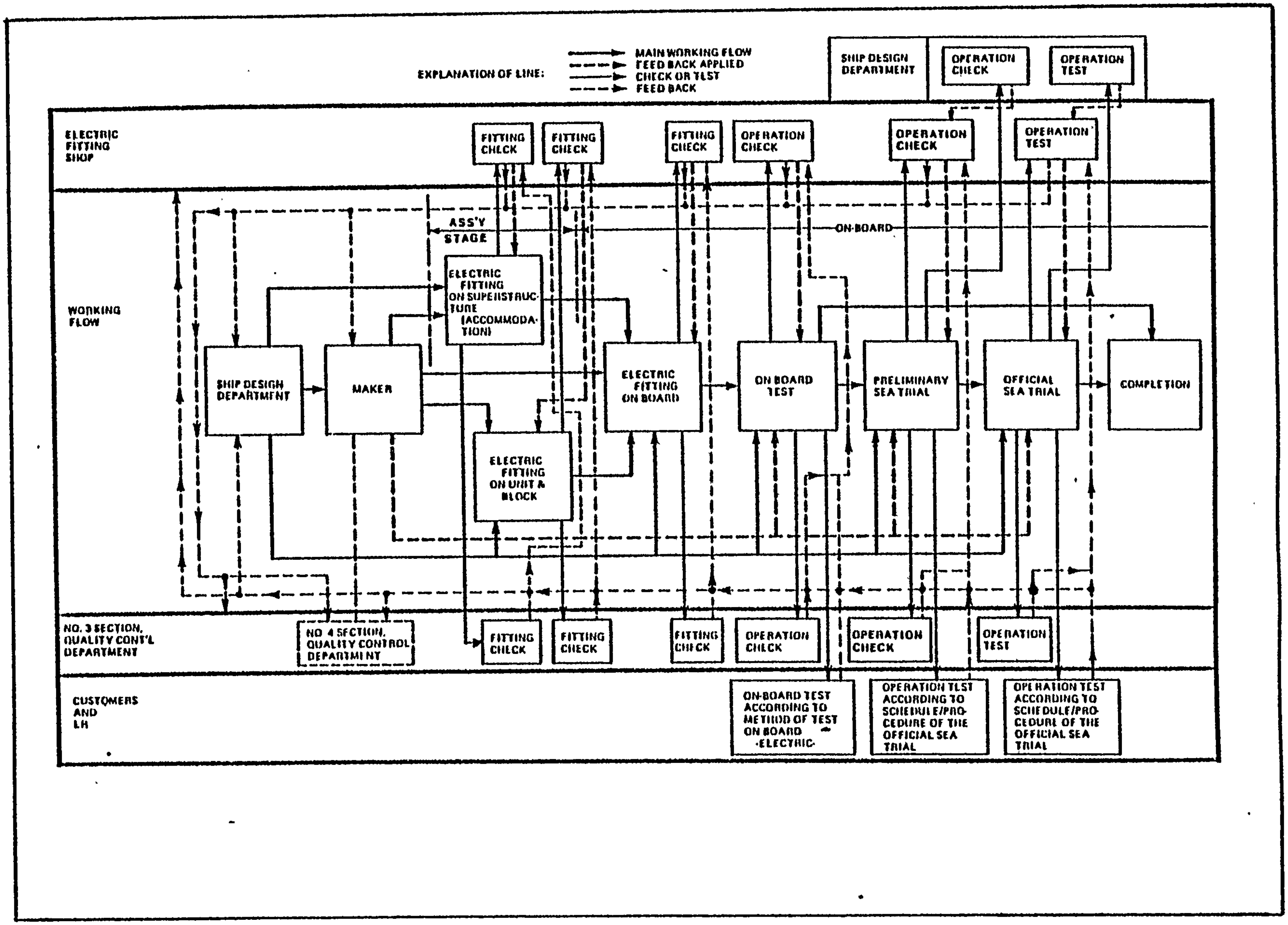


FIGURE 4-8 QUALITY CONTROL CHART (ELECTRIC) (IHI)

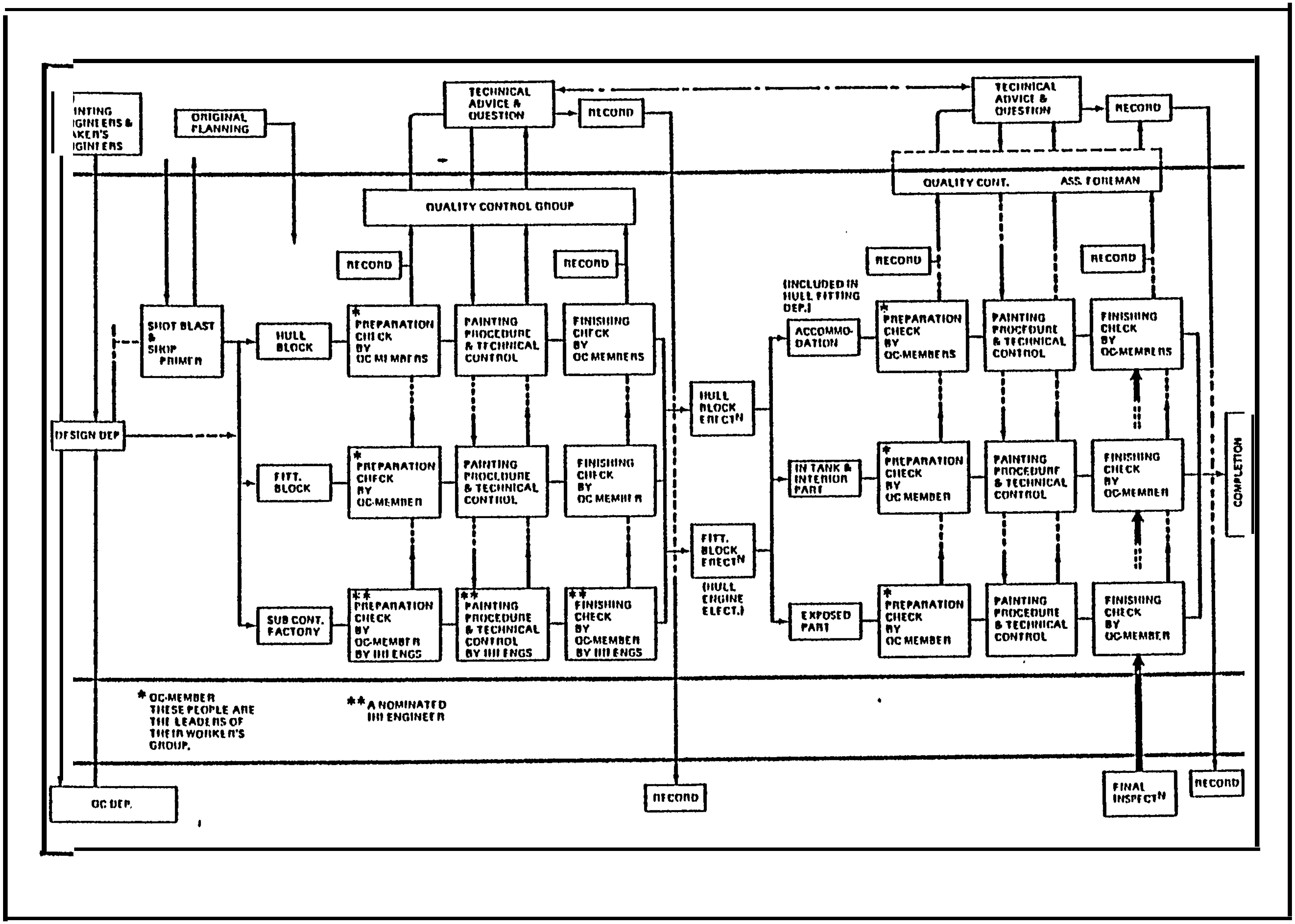


FIGURE 4-9 QUALITY CONTROLL FLOW CHARTT (PAINTING)

P/E
L0T
W/U

W. Q. C. CHECK SHEET

	SUB ASSEMBLY (内業)
	ASSEMBLY (大組)
	ERECTION (外業)

S.No.		BLOCK OR TANK		溶接長 WELD LENGTH	METERS	場所 SHOP	

GRADE 等級	CHECK POINT チェック項目 / CHECKER	作業リーダー LEADER	QC 1	REP 手直し	品質管理係 QC MEMBER	QC 2	REP 手直し	検査担当 INSPECTOR	減 点 数		REP 手直し
A	CRACK 割れ								11×		
	MIS-USE OF ELECTRODE 溶接材料の選定								11×		
	WELD OMITTED 溶接忘れ (300mm 1 POINT)								11×		
B	LEG LENGTH 脚長 0.9L > L1 L: Leg Length on Plan 図面脚長 300 mm 1 POINT								4×		
	UNDERCUT アンダーカット BUTT IN SKIN & FACE E IN 6L III ≦0.5 300mm 1POINT								4×		
	OTHERS ≦0.8								4×		
	RETURN WELD 角廻し (5 DEFECTS : 1 POINT)								4×		
	BACK GOUGING ウラ掘り										
C	BEAD APPEARCE ビード外観 LOW BEAD 余盛不足 REINFORCEMENT 300mm 1POINT								2×		
	SHORT BEAD MIN.50M.T. ショートビード 〃 30M.L. SURFACE ブローホール POROSITY ピンホール 等 5DEFECTS 1POINT								2×		
	スラグ除去								2×		
D	REMOVAL OF TEMP. FITTING & WELD								2×		
	REPAIR OF U.CUT AFTER REMOVAL OF TEMP. W. アンダーカットの手直し								2×		
	GAS NOTCH 切込みキズの手直し								4×		
	ARC STRIKE アークストライク								2×		
	OTHER MINOR ITEMS その他 (5 DEFECTS : 1 POINT)								減点小計		

SUMMARY	作業リーダー LEADER	A	B	C	D	品質管理係 QC MEMBER	A	B	C	D	検査 INSPECTOR	A	B	C	D
備考	— DO —					— DO —					作業リーダー LEADER	月 日		月 日	
REMARKS							[illegible]		[illegible]		品質管理係 QC MEMBER				
							減点合計				検査 INSPECTOR				
	FAT										等級 CLASS				

FIGURE 4-10

A. Q. C. CHECK SHEET

	SUB ASSEMBLY	(小組)
	ASSEMBLY	(大組)
	ERECTION	(外業)

S.No.		BLOCK OR TANK		ブロック重量 BLOCKWEIGHT	TONS	場所 SHOP	

GRADE 等級	CHECK POINT チェック項目 / CHECKER	作業リーダー LEADER QC 1	REP 手直し	品質管理係 QC MEMBER QC 2	REP 手直し	検査担当 INSPECTOR	減 点 数		REP 手直し
A	MISFITTING 誤作、つけ忘れ						11× 4×		
A	SCANTLING CHECK 寸法不足						11× 4× 2×		
B	MISALIGNMENT 目ちがい (主要部材 MAIN STR / その他 OTHERS) BUTT つき合せ: < 0.15t / < 0.2t, MAX. 3						4×		
B	FILLET すみ肉: < t/3 / < t/2						4×		
B	GAP ギャップ BUTT: G≤5; 5 < G ≤ t/2 ウラ当て; t/2 < G < t ウラ当て 部分取替						4×		
B	FILL: G≤3 増脚長; 3<G<5 面取りのみ; 5<G<t ウラ当て						4×		
B	DEFORMATION 歪 (TANK 部 P & A) IN SHELL 外板 ≤6 ≤7 DECK デッキ ≤6 ≤8 TANK TOP タンクトップ ≤8						4×		
B	BHD 隔壁 ≤8 GIRD. TR トランス ≤8						4×		
C	GAP ギャップ LAP(重ね)						4×		
C	DEFORMATION 歪 IN FL. & G. IN DB 二重底内フロアガーダー ≤8 BKT ≤2t/3						2×		
C	STIFF & BEAM HOUSE WALL ≤8						2×		
C	FCPLの折れ曲り 4.5mm/100mm 部材の傾斜 5°						2×		
D	NOTCH ノッチ EDGE ROUGHNESS ガスキズ						4× 2×		
D	OTHER MINOR ITEM その他 (5 DEFECTS : 1 POINT)						減点小計		

SUMMARY	作工リーダー LEADER	A	B	C	D	品質管理係 QC MEMBER	A	B	C	D	検査 INSPECTOR	A	B	C	D
備考 REMARKS	—DO—					—DO—					作業リーダー LEADER	月 日		月 日	
											品質管理係 QC MEMBER				
											検査 INSPECTOR				
											総級 CLASS				

FIGURE 4-10

work has been moved to another work station. The sheet is also used by assistant foremen to remedy continuing problems in cutting, fitting or welding by identifying persistent problems and either obtaining a correction in design or .educating. workers in proper techniques to prevent a recurrence.

During the processing of steel, each welder identifies his work by signing each weld he has made. By this means the group leader and checker/ inspectors can identify the individual responsible for the work. In outfitting,work is identified to a specific work group by reference to schedules and work locations. This is done in each stage of production. A weighted factor (based on the importance of the work performed) is applied by the inspector to each error to achieve a summary “grade” or “bad mark” for each item inspected. The purpose of this system is related only to each individual’s pride in his workmanship. No disciplinary action is taken as a result of “bad marks”, it is simply a means of publicizing superior or poor work both to the individual worker and to.his work group. These records are also used to assess the performance of each group. Throughout the shipyard quality control statistics for work groups and production units are posted to continually reinforce quality awareness.

Throughout the Quality Control process the “group” is emphasized rather than individual performance. Each assistant foreman controls a group of five to eight people who work together in one location on one activity throughout a production run. The productivity and welfare of the group is paramount and takes precedence over individual concerns. If an individual is having a work problem other members of the group will help him overcome it. If he has a personal problem away from work the assistant remen, foreman or Industrial Relations group will try to assist in its resolution. A true group spirit seems to be evident throughout the shipyard and personnel welfare is highly stressed by all management personnel.

4.4 CONCLUSION

The combined functions of Accuracy Control and Quality Control provide a complete system of Quality Assurance for the shipyards of IHI. This system assures high quality through its thorough planning of fabrication methods, required measurements, template development and subsequent field measurement to assure adherence to prescribed standards and accuracy control requirements.

The outstanding aspects of this system lie in the emphasis placed on accuracy during the earliest design stages and the continuous refinement of the planning, design and production processes throughout the production cycle.

The many ramifications of this Quality Assurance system extend across all shipyard activities and ultimately influence the work habits and attitudes of all personnel employed in ship construction. In IHI the system's objectives have become integral to every aspect of the production process and these objectives underlie and form the basis for the progressive and continual improvement of the total shipyard system. These elements of Quality Assurance (i.e. Accuracy Control and Quality Control) are, to a significant degree, responsible for the high productivity characteristic of the IHI shipyards.